SPECIES ADAPTABILITY IN THE PICEANCE BASIN FOR REVEGETATING SOILS DISTURBED BY OIL SHALE DEVELOPMENT

Final Report

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Area Oil Shale Office

USGS

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INTRODUCTION

This research is a continuation of studies initiated in 1972 (Sims and Redente 1974) to test species adaptability in the Piceance Creek Basin of Colorado. The intent of further research was to test and rate certain native and introduced species of grasses, forbs, and shrubs and determine their value in revegetating semi-arid locations. Additional data on natural re-invasion was collected and compared with earlier results to determine secondary successional trends based on changes in species composition.

Although the results of this research are applicable to most disturbed lands in the foothills and intermediate zones of the Rocky Mountain area, care must be exercised to avoid applying this information to areas that are not suited. Proper extrapolation of research results requires trained individuals familiar with both the area of disturbance and the vegetation in relation to the site potential.

Other studies in semi-arid regions similar to the Piceance Basin have shown the fragile nature of these ecosystems and the need for immediate soil stabilization. For this reason, the need for future studies in semi-arid land rehabilitation will be of continued importance as long as surface disturbances occur.

STUDY AREA

During the summer of 1972 four major vegetation types were selected in the Piceance Creek Basin according to relative productivity and percent of total land area occupied (Sims and Redente 1974). The four vegetation types included: 1) Mid Elevation Big Sagebrush Shrubland, 2) Low Elevation Pinyon-Juniper Woodland, 3) High Elevation Pinyon-Juniper Woodland, and 4) Mixed Mountain Browse (Shrubland). A research plot was chosen in each vegetation type according to vegetation cover, slope and aspect. Each location chosen includes both an unfavorable harsh site and a favorable site in order to get a better representation of the natural ecosystems throughout the basin. The favorable sites were primarily level in slope with relatively high vegetation cover and production. The harsh sites were either a south, west or northwest exposure with steeper slopes and relatively low plant production and cover.

Each test site was set up in a completely randomized split-split plot design with two replications on each site along with two treatments (Figures 1, 2, 3, and 4). After the experimental design was determined, treatments were then applied to each site. The two surface disturbances that were applied included: 1) vegetation removed by scraping with a minimum of topsoil loss and 2) plowing to a depth of 20 to 30 cm after removal of the vegetation. The sites were then fenced to exclude cattle and wild horses with a standard four strand barbed wire fence.

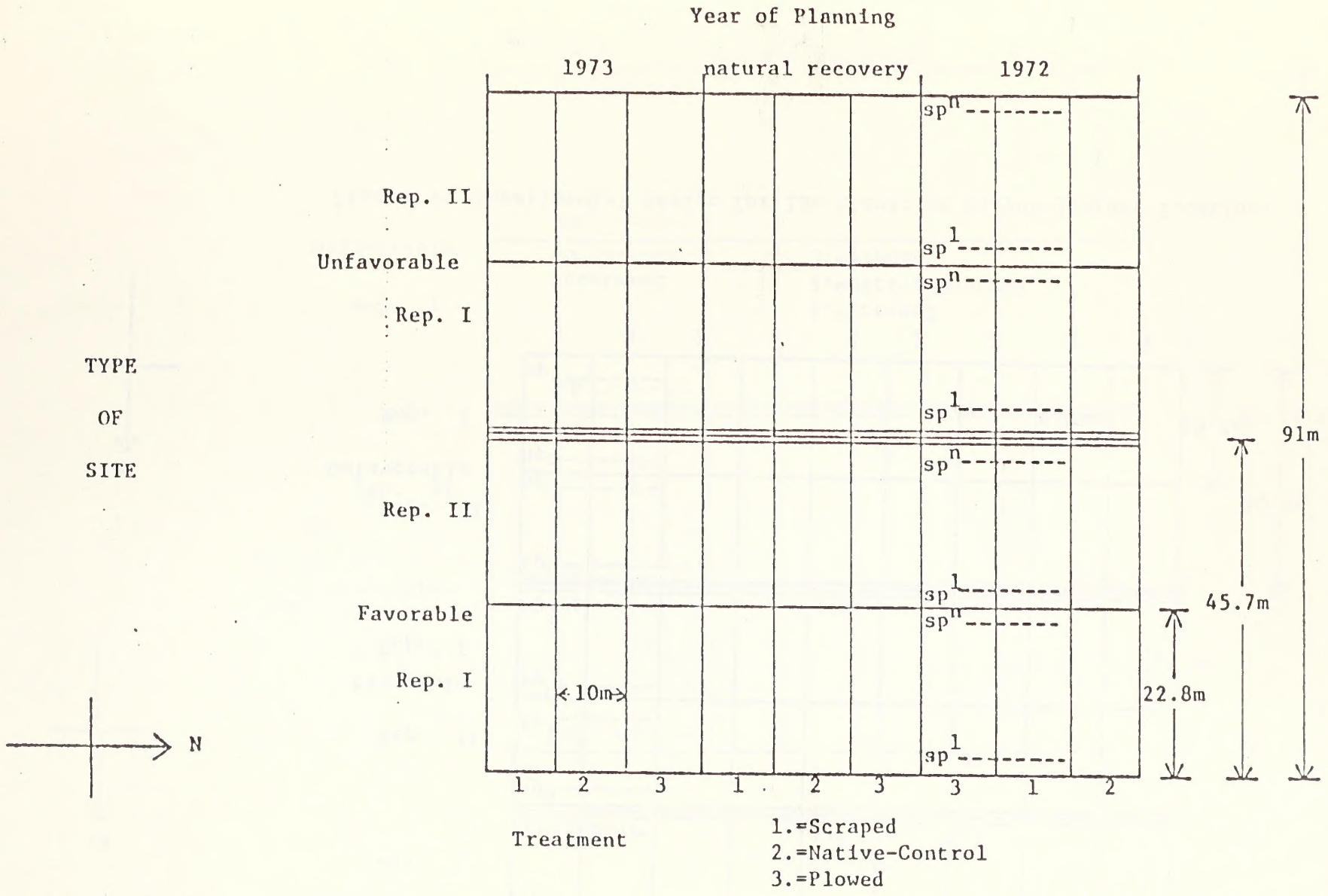

Figure 1. Experimental design for sagebrush location.

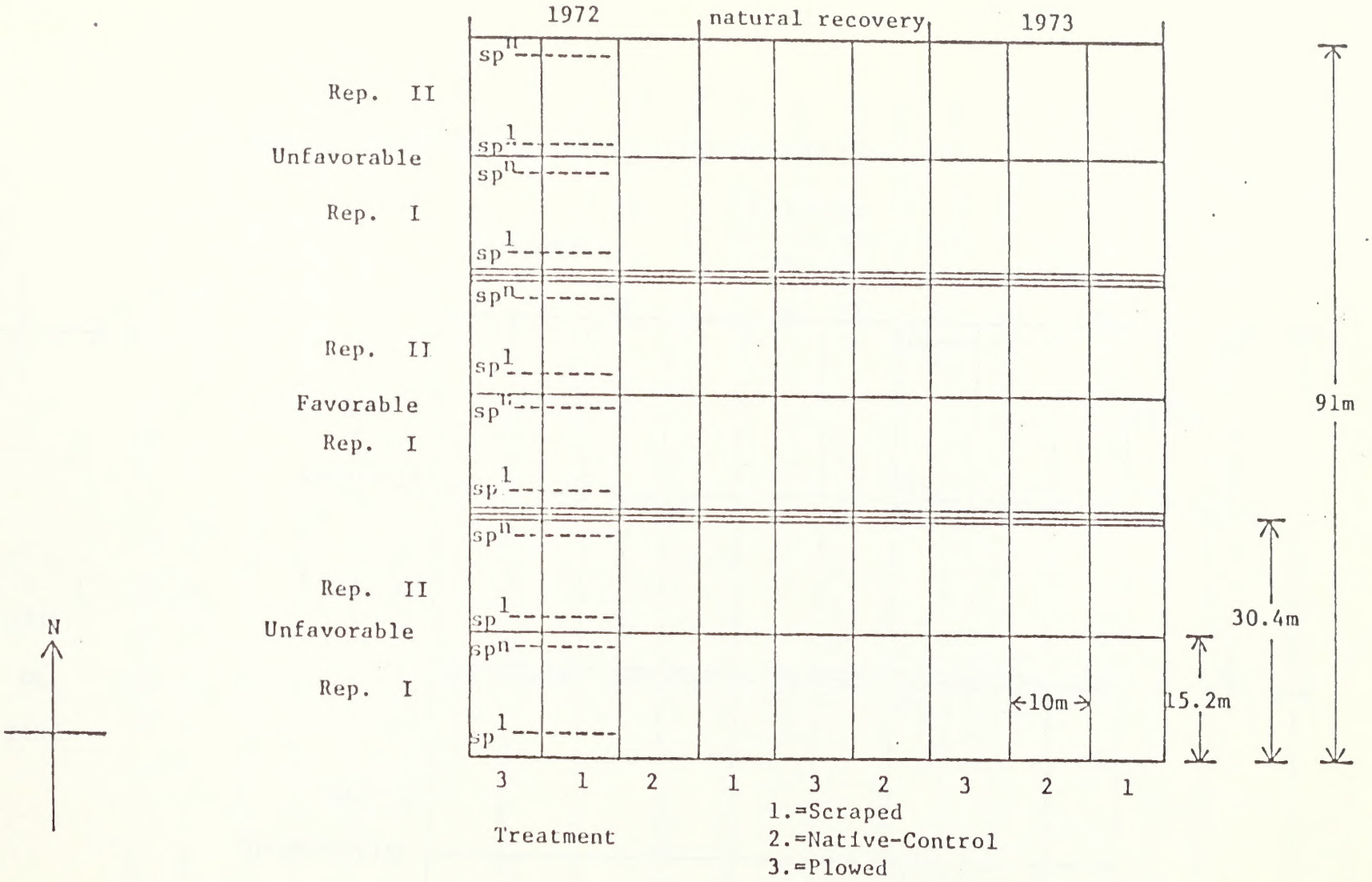

Figure 2. Experimental design for low elevation pinyon-juniper location.

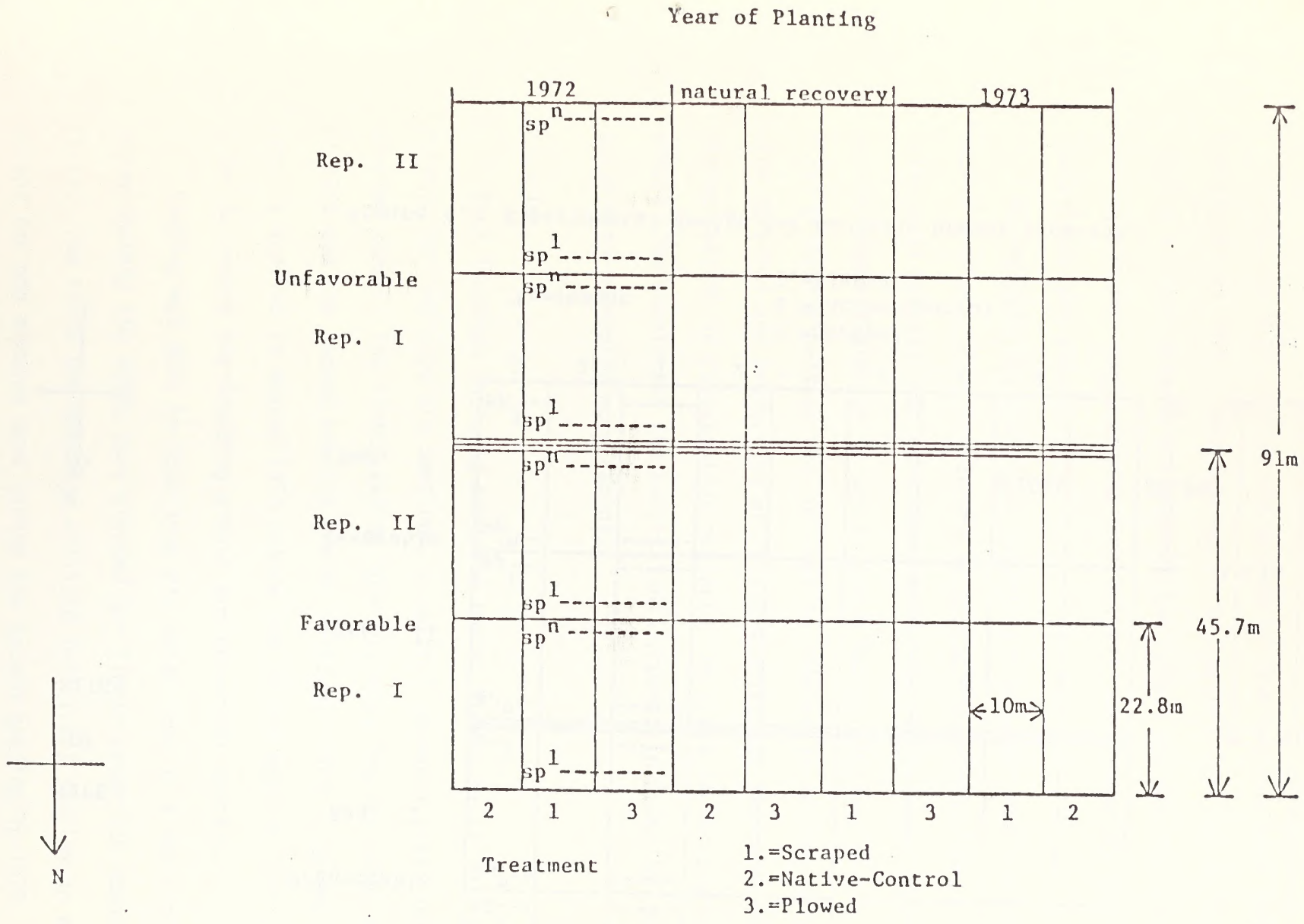

Figure 3. Experimental design for high elevation pinyon-juniper location.

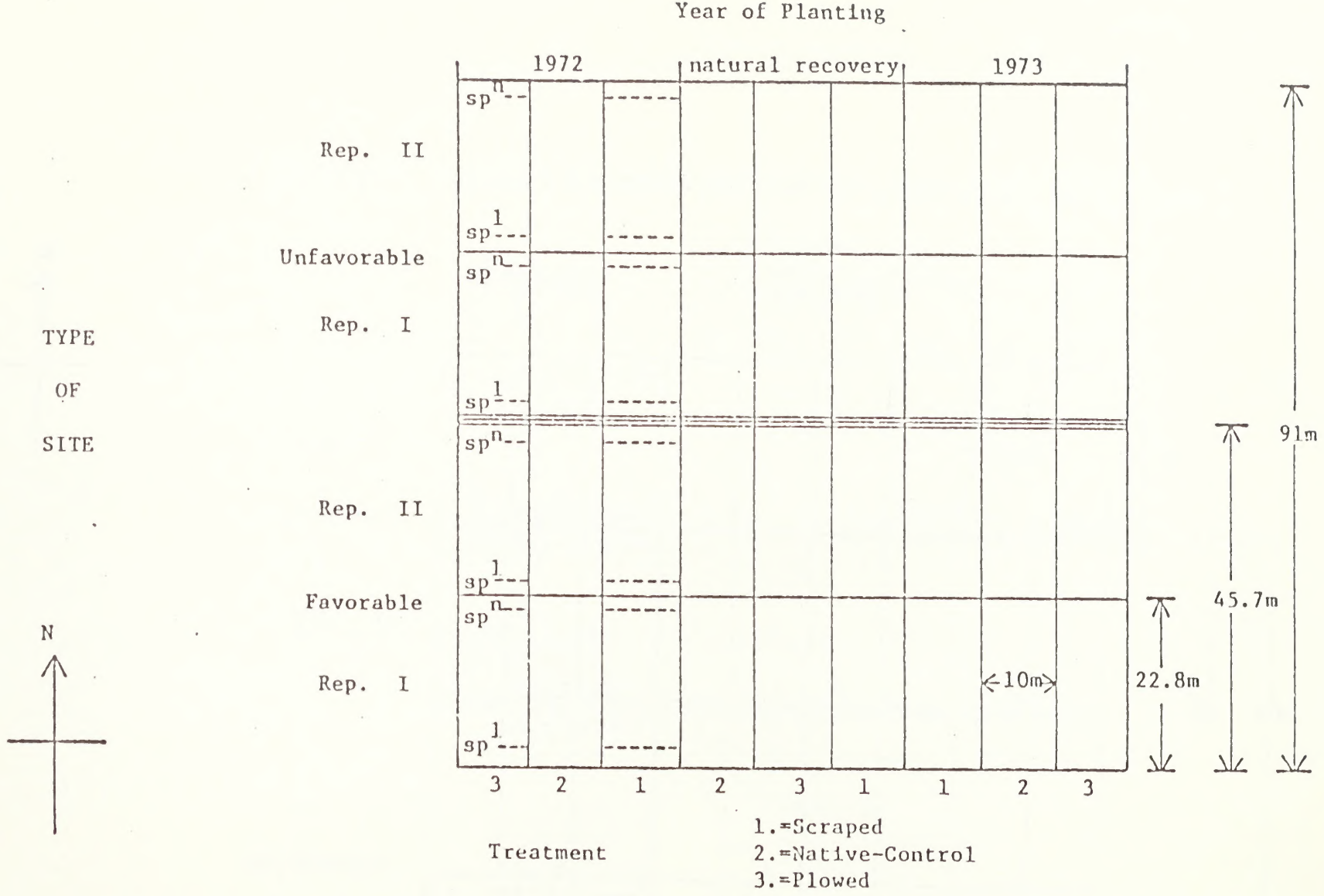

Figure 4. Experimental design for mountain browse location.

Species Selection

Seed for each species was purchased from various seed companies during the summer of 1972. Some species were obtained from the Soil Conservation Service's Plant Materials Center in Los Lunas, New Mexico, while the remaining species were acquired from private seed companies in Colorado, Utah, Idaho and Kansas.

An emphasis was placed on native species when ordering seed. As many native grasses, forbs and browse as possible were obtained, along with introduced species that were found to be superior in past seeding trials in environments similar to the Piceance Basin. Native species were emphasized primarily because the information related to seeding methods, along with survival and production of native species was limited. The use of native species in revegetation projects, in place of introduced species, should also accelerate the successional process in order to reach a self sustaining ecosystem more rapidly.

Planting

Each location included adequate space, approximately 0.8 hectare (2 acres), for two separate seedings, a natural recovery area, and native control zones. The first seeding took place during September and October of 1972 and the second seeding during September 1973. The two treatments were re-applied in August 1973 before the second seeding took place in order to remove the invading annual and perennial species.

Seeding was done by hand into six meter rows at a depth of 1.27 cm. Approximately 150 seeds were planted per linear meter (50 seeds per linear foot). The first two seedings utilized individual species in each row except for one mixture used during the second seeding in 1973.

Previous Data Collection Periods

Information was collected by Sims and Redente (1974) during the spring, summer and fall of the first growing season (1973) and again in the summer of the second growing season (1974). Each seeded row was observed and rated on a scale of 0, 1, 2, 3, or 4, which represented none, poor, fair, good, and excellent emergence or survival, respectively. This procedure was used at each location to gather qualitative information concerning emergence during the first growing season and emergence and survival during the second growing season. Seedlings were also counted during the first growing season to acquire quantitative information on emergence.

Natural Recovery

The center one-third of each location was scraped and plowed, and then left for natural revegetation to take place. Because of the limited data available on natural recovery from surface disturbances in the Piceance Basin, information collected here was considered to be essential in future revegetation programs.

METHODS AND MATERIALS

Emergence and Vigor

Qualitative data on emergence and vigor of seeded species was gathered during the spring, summer, and fall of 1975 and 1976. Species were again rated on a scale of 0-4 which represented no emergence or vigor, poor emergence or vigor, fair emergence or vigor, good emergence or vigor, and excellent emergence or vigor, respectively. The emergence and vigor data was used to compile a list of suitable species for revegetation in the Piceance Basin.

Quantitative data was also obtained in the summer of 1975. This involved stretching a small gauge string across the seeded rows, and at four random points counting the seedlings falling in a 30.48 cm (12 inches) distance along the line of the stretched string.

The data collected in the spring, summer, and fall of 1976 was for the fourth growing season of the 1972 seeding and the third growing season of the 1973 seeding.

Natural Recovery

Daubenmire (1959) outlined the method of sampling used on the natural recovery areas. These areas constituted the middle one-third of each location. The process involved the random placement of a 0.1 m^2 quadrat and estimating the appropriate cover and biomass for each individual species encountered. Each third estimate was weighed to check the accuracy of the biomass estimate (double sampling technique).

Results obtained on the natural recovery areas will aid in determining the potential time frame and species compositions of the various successional stages involved in the natural recovery of surface disturbed locations in climates similar to that of the Piceance Basin.

Method of Analysis

Percent frequency and percent total cover were determined for each species on the natural recovery areas. This involved the use of Daubenmire's (1959) Canopy-coverage method of vegetation analysis. Resulting data gives a two-dimensional evaluation between species influences and interactions (with each other and other components of the ecosystem).

The seeded species were rated for emergence and vigor (as previously outlined) and tabulated results were compared to t-test values at a .05 level of probability between species on the four study locations.

Precipitation Data

Precipitation data was obtained from the Little Hills Experiment Station's monthly climatological data compiled by the United States Department of Commerce (1971-1976) (Appendix, Tables 1 and 2). Data was measured on site by using rain gauges constructed by Sims and Redente (1974) to give approximate local precipitation amounts.

Soils Information

The Soil Conservation Service conducted soil surveys on each location (Appendix, Table 3). These surveys are helpful tools in determining and understanding some of the plant soil relationships present in the Piceance

Basin and as a key to vegetation growing on certain soils and the limits of such interpretations.

RESULTS AND DISCUSSION

The initial portion of this section deals with species evaluation of the planted varieties. The second portion examines the data compiled on the natural recovery zones.

Evaluation of Seeded Species

The species observed in the 1975 and 1976 sampling periods can be grouped into three categories. The first of these included species well adapted to conditions present on the site. The second grouping was assigned to those species showing some promise for revegetation, but not enough to be used as potential species by themselves. These species would be included to fill gaps and add diversity with the well adapted vegetation. The last classification was designated for species showing little promise and poor site adaptability.

To classify as a well adapted species, a seeded species must show superior seedling and yearly emergence and vigor. The species were rated on a scale of 0-4, as detailed in methods and materials. The species were rated with relation to 1976 observations and the previous years' compiled data (1972-1975). The well adapted species have averages in the neighborhood of two to four. The seeded species are evaluated by site in relation to the best seeded stand present therein. That is to say, species on the sagebrush plot are not rated in relation to those on the mountain browse, but in relation to their own site location.

In the grouping for species showing some promise, species must have averages ranging roughly from .8 to 1.9, or in the case of shrubs, sufficient plant growth and size to warrant its continuation in revegetation work. Those species showing less than .8 are grouped in the final category. These species are only marginal, at best, for the sites and conditions studied.

Each of the four sites sampled will be discussed and the species will be placed in the various categories. The four sites are: mid-elevation sagebrush, low-elevation pinyon-juniper, high-elevation pinyon-juniper, and mixed mountain browse shrubland.

The species included in the well adapted category contain species with either late or early summer vitality, or a combination of both. Since some vegetation is noticeably more vigorous in the cooler, moister portion of the early summer season, and other vegetation show more vitality throughout the summer, it is necessary to include portions of each to insure continued soil stabilization and forage for domestic and wild herbivores. By conducting vegetation ratings in the early summer and late summer months, such information was gathered. The following descriptions contain the species which exhibit the desired combination of traits necessary to establish a successful revegetated community.

Mid-Elevation Sagebrush Location

Site Description

The sagebrush site occurs at an elevation of 1,988 m (6,522 feet) and receives from 33 to 38 cm (13 to 15 inches) of annual precipitation. The legal description is T. 1S., R. 98 W., Sec. 19, SW¼, SW¼, NW¼. The seeded treatments occurred on an unfavorable west facing slope (4:1) with the favorable level area directly east of it.

Species Evaluation

Grasses

Those grasses showing excellent adaptation included a majority of the seeded introduced wheatgrasses. They have continued to do well and have very consistent year to year emergence and vigor ratings. Of these, Oahe and Amur intermediate wheatgrass,[1] Critana thickspike wheatgrass, Rosana western wheatgrass, Siberian wheatgrass, Nordan crested wheatgrass, Luna pubescent wheatgrass, Sodar streambank wheatgrass and Jose tall wheatgrass show great potential in future rehabilitation work.

The brome grasses also showed good adaptation on this site. Both mountain brome and Regar meadow brome have been consistent performers through the sampling periods. Other species well adapted to this site include Sawki Russian wildrye and green needlegrass.

Species showing intermediate adaptabilities for revegetation work included a good variety. Again, several wheatgrasses are present. Among these are: C-30 western wheatgrass, bluebunch wheatgrass, and slender wheatgrass. Shermans big bluegrass and Kentucky bluegrass are two of the *Poa* species that occur here.

The wildryes were also quite prevalent in this group. Salina wildrye and C-43 basin wildrye fall into this category. Other grasses that are grouped with the above are: Durar hard fescue, orchardgrass, Timothy, Indian ricegrass, and Manchar brome.

Those grass species showing little promise in revegetation work are: sand dropseed, alkali sacaton, galleta, Arizona fescue, and Griffiths wheatgrass.

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[1]Scientific Names in Appendix, Table 4.

Broadleafed Forbs

Of this listing, those species showing excellent adaptation are: arrowleaf balsamroot, Palmer penstemon, Lewis flax, and gooseberryleaf globemallow.

Species with intermediate adaptation included Rocky mountain penstemon, Pacific aster, and bouncing-bet.

Species showing no promise included small burnet, sweetanise, aster and verbena.

Leguminous Forbs

The seeded legumes which were well adapted included several vetch species. These are: Penngift crownvetch, Utah sweetvetch, and astragalus.

Both rambler and rhizoma alfalfa had excellent emergence and vigor. Madrid yellow sweetclover also performed well on this site. Two vetch species, sicklepod and Lutana cicer milkvetch, were somewhat adapted to this site.

Only two legumes seemed poorly adapted to this site. Mountain lupine and purple prairie clover had very poor establishment success and did not exhibit adequate plant vigor.

Shrubs

A consistent species through the years has been green ephedra. It has displayed excellent adaptability from year to year and shows great promise for future seedings. Other well adapted shrub species included yellowbrush, winterfat, Stansbury cliffrose, antelope bitterbrush and shadscale saltbush.

Only a few species were partially adapted on this site. Desert bitterbrush, fourwing saltbush, big sagebrush, Gardner saltbush and Nuttall saltbush exhibited some success.

The list of unadapted species is long. True, curl-leaf and birchleaf mountain mahogany all did poorly. Snowberry, winterberry, silver buffaloberry and serviceberry also showed little promise. Desert peachbrush, black sagebrush and rubber rabbitbrush also did poorly. Other poorly adapted species included: desert molly, common bladdersenna, black chokecherry, ceanothus deerbrush, squawcarpet, blueberry elder, skunkbush sumac, New Mexico forestiera and Russian olive.

Selected Species for Seeding

If regulations demand replacement of only native species a good combination of grasses, forbs and shrubs is available. Species that would do well on this location include: Critana thickspike wheatgrass, Sodar streambank wheatgrass, Rosana western wheatgrass, mountain brome and green needlegrass. Acceptable native broadleafed forbs would include Lewis flax, Palmer penstemon, and arrowleaf balsamroot. Good legumes available are Utah sweetvetch and penngift crownvetch. Native browse species would include green ephedra, yellowbrush, winterfat, Stansbury cliffrose, antelope bitterbrush and shadscale saltbush.

If both introduced and native species can be used, all the species mentioned in the well adapted category would give excellent results.

Low-Elevation Pinyon-Juniper Location

Site Description

The low pinyon-juniper site is situated at 1,952 m (6,404 feet) in elevation and receives approximately 33 to 43 cm (13 to 17 inches) of annual precipitation. The legal description is: T. 1N., R. 97 W., Sec. 20, NE¼, SE¼, SE¼. The site consisted of three expressions. The favorable expression (situated on the level hill top) occurred between the unfavorable north exposure (on a 4:1 slope) and the unfavorable south exposure (3:1) slope. The low pinyon-juniper site represents the eroded slopes along the valley bottoms and ravines. These appear as light colored shale exposed areas throughout the Piceance Basin.

Species Evaluation

Grasses

A large number of grass species, particularly exotic species, are well adapted to this location. The introduced and native wheatgrasses are again impressive in year to year stand evaluations and vigor. Those exhibiting excellent characteristics are Amur and Oahe intermediate wheatgrass, Nordan crested wheatgrass, Critana thickspike wheatgrass, Sodar streambank wheatgrass, Siberian wheatgrass, Rosana western wheatgrass, Luna pubescent wheatgrass. Two native species, slender wheatgrass and bluebunch wheatgrass, also had excellent stands. The use of these grasses in a revegetation plan can greatly increase the success of the rehabilitation process.

Surprisingly, the brome grasses also did quite well on this site. Both Regar meadow brome and Manchar smooth brome showed encouraging results.

Other grasses that showed excellent adaptability were Sawki Russian wildrye, green needlegrass and Timothy.

Those species that were intermediate in adaptability include several genus of grass. Several wheatgrasses are included in this group. Among these are: Jose tall wheatgrass, Barton western wheatgrass, and C-30 western wheatgrass. Both C-43 basin wildrye and Salina wildrye fall into this category. Other species include Shermans big bluegrass, Kentucky bluegrass, orchardgrass and Indian ricegrass.

Seeded species showing poor adaptability included: Griffiths wheatgrass, Arizona fescue, alkali sacaton, sand dropseed, and galleta.

Broadleafed Forbs

Forb species showing excellent adaptability were Lewis flax, small burnet, gooseberryleaf globemallow and arrowleaf balsamroot. These species were constant by the years, and have remained productive throughout the yearly samplings. Forbs showing varying adaptability on the low pinyon-juniper site included: Pacific aster, sweetanise, Palmer penstemon and bouncing-bet.

The *Aster* species was the only seeded broadleafed forb showing little promise in revegetation. Little or no emergence was noted for this species on this site.

Leguminous Forbs

There was quite an array of well adapted legumes on this site. The vetch species: Sicklepod milkvetch, Penngift crownvetch, and the *Astragalus* species appeared to be excellent choices for revegetation on this site. The alfalfas also did well; both rambler and rhizoma alfalfa exhibited excellent

characteristics. Madrid yellow sweetclover also did well on this site. Both Lutana cicer milkvetch and Utah sweetvetch seemed variable in adaptability on the low pinyon-juniper site.

Of the legumes, only purple prairie clover seemed wholly unacceptable as a potential revegetation species. As on all sites, purple prairie clover did very poorly on the low-elevation pinyon-juniper site.

Shrubs

The list of shrubs showing excellent adaption on this site is rather limited. Green ephedra, again, showed superior adaption to these site conditions. Yellowbrush and winterfat were the only other shrubs showing a good degree of promise.

The list of species showing intermediate success on this site is a bit longer. Serviceberry and snowberry showed signs of their value in a revegetation plan. Other species included: true mountain mahogany, rubber rabbitbrush, and Stansbury cliffrose.

Many of the shrub species studied were apparently unadapted to this site. Both big sage and black sage exhibited poor adaptability. The saltbush species also faired poorly on this site. Fourwing saltbush, shadscale saltbush, Gardner saltbush and Nuttall saltbush showed little promise here. Other poorly adapted shrubs were desert molly, skunkbush sumac, burchleaf mountain mahogany, silver buffaloberry, ceanothus deerbrush, and ceanothus squawcarpet.

Selected Species for Seeding

If regulations dictate replacement of native species a good list of species are available. The wheatgrasses again comprised the majority of

acceptable species. Species to use include: Rosana western wheatgrass, Critana thickspike wheatgrass, Sodar streambank wheatgrass, slender wheatgrass and bluebunch wheatgrass. Other natives that could be used would include Indian ricegrass (if a good seed source is available) and green needlegrass.

Acceptable broadleafed native forbs to include would be: Lewis flax, gooseberryleaf globemallow and arrowleaf balsamroot. The following legumes also have good potential: Penngift crownvetch, and possibly Utah sweetvetch.

Only three shrub species could be included in a native mix. Green ephedra, yellowbrush and winterfat would be used.

If a mixture of native and introduced species could be applied, all the species in the well adapted categories would be acceptable to include in a rehabilitation plan.

High-Elevation Pinyon-Juniper Location

Site Description

The high pinyon-juniper site receives approximately 35 to 45 cm (14 to 18 inches) of annual precipitation and occurs at an elevation of 2,123 m (6,965 feet). The legal description of the site is: T. 3S., R. 97W., Sec. 13, NE¼, SE½, NE¼. The seeded treatments occurred on a favorable, gently sloping north to northeast exposure and a steeper (4:1 slope) south facing expression.

Species Evaluation

Grasses

Numerous well adapted grasses are available for this location. As in the previous sites, the wheatgrasses constituted a majority of potentially useful revegetation species. Nordan crested wheatgrass, Amur and Oahe intermediate wheatgrass, Jose tall wheatgrass, Rosana western wheatgrass, Sodar streambank wheatgrass, Siberian wheatgrass, Luna pubescent wheatgrass, and Critana thickspike wheatgrass were all consistent performers.

The brome grasses also did well on the high pinyon-juniper site. Their performance here, as in the previous sites, was encouraging. Regar meadow brome, mountain brome and Manchar brome showed excellent growth habits and persistence on the site. Other excellent species included Indian ricegrass, Durar hard fescue and green needlegrass.

Several species also showed intermediate adaptability on this site. This included several wheatgrasses such as: Barton western wheatgrass, slender wheatgrass, C-30 western wheatgrass and bluebunch wheatgrass.

Other partially adapted species included: Shermans big bluegrass, Kentucky bluegrass, C-43 basin wildrye, Sawki Russian wildrye, Salina wildrye, orchardgrass, and Arizona fescue.

Species apparently poorly adapted to this site were: Griffiths wheatgrass, alkali sacaton, sand dropseed, galleta, and Timothy.

Broadleafed Forbs

Generally, broadleafed forbs did very well on this site. The well adapted species included: arrowleaf balsamroot, bouncing-bet, small

burnet, Lewis flax, Palmer penstemon, Rocky mountain penstemon, gooseberryleaf globemallow, and verbena. Those species of intermediate adaptability included: Pacific aster, sweetanise and a mixture of broadleafed and leguminous forbs which included an *Astragalus* species, a Penstemon species and purple prairie clover. Of the broadleafed forbs, none seemed wholly unacceptable for incorporation into a rehabilitation plan on this site.

Leguminous Forbs

The vetch and alfalfa species also gave excellent results on this site. Utah sweetvetch, rambler and rhizoma alfalfa displayed excellent adaptability. The partially adapted species included: Penngift crownvetch, sicklepod milkvetch, Lutana cicer milkvetch and the seeded Astragalus species. Mountain and silky lupine and purple prairie clover were poorly adjusted to this site and showed very little promise for revegetation.

Shrubs

There is quite a good selection of shrubs available on the high pinyon-juniper location. Green ephedra did well here, as did yellowbrush. Other species showing promise included: antelope bitterbrush, Stansbury cliffrose, desert bitterbrush, and common bladdersenna. This site seems well adapted to shrubs and consideration should be give to their use in future programs.

Species showing intermediate adaptability included: winterfat, Russian olive, big sagebrush, rubber rabbitbrush, true mountain mahogany, and black chokecherry.

There were many unadapted shrubs on this site. Examples included: fourwing, shadscale, Gardner and Nuttall saltbush. Other poorly adapted species included: winterberry, serviceberry, snowberry, silver buffaloberry, ceanothus deerbrush and squawcarpet, desert peachbrush, desert molly, black sagebrush, birchleaf mountain mahogany, blueberry elder and skunkbush sumac.

Selected Species for Seeding

For strictly a native reseeding venture, there is a very good selection of species to choose from. Selected grasses would include: Critana thickspike wheatgrass, Rosana western wheatgrass, Sodar streambank wheatgrass, mountain brome, green needlegrass and Indian ricegrass.

Well adapted native forbs would include: of the broadleafed ones, arrowleaf balsamroot, Lewis flax, Palmer penstemon, Rocky mountain penstemon, verbena, and gooseberryleaf globemallow. Utah sweetvetch would be an excellent legume to include.

Adapted native shrubs would be: yellowbrush, ephedra, Stansbury cliffrose, common bladdersenna, desert bitterbrush, and antelope bitterbrush.

If combinations of native and introduced species are used, all the species falling into the well adapted category would give excellent results.

Mountain Browse Location

Site Description

The mountain browse site occurred at the highest elevation (2,440 m or 8,005 feet) of all four sites, and received the greatest amounts of total annual precipitation (45 to 55 cm, or 18 to 22 inches). The legal description is: T. 4S., R. 97W., Sec. 14, NE¼, NE¼, NW¼. Two different expressions or aspects were studied on the mountain browse location. The first expression occurred on a gently sloping northwest exposure (favorable site) and the second, a steeper (4:1 slope) northwest aspect (unfavorable site).

Species Evaluation

Grasses

The mountain browse location showed the largest number of well adapted species. The wheatgrasses were joined by a greater variety of grass genera and a good mixed community occurred. The wheatgrasses showing excellent characteristics included: Nordan crested wheatgrass, Critana thickspike wheatgrass, Jose tall wheatgrass, Amur and Oahe intermediate wheatgrass, Rosana western wheatgrass, Sodar streambank wheatgrass, Barton western wheatgrass, slender wheatgrass, bluebunch wheatgrass, and Luna pubescent wheatgrass.

The brome grasses and wildryes also did very well on the mountain browse site. Mountain brome, Regar meadow brome, and Manchar brome showed excellent sampling results. Both C-43 basin wildrye and Sawki Russian wildrye exhibited excellent characteristics. Other well adapted grass species included are: Durar hard fescue, Arizona fescue, green needlegrass, and Timothy.

The list of intermediately adapted species is somewhat smaller than other locations. The species included in this category were Indian ricegrass, Kentucky bluegrass, Shermans big bluegrass, orchardgrass, and Salina wildrye.

The list of unadapted species includes Griffiths wheatgrass, alkali sacaton, sand dropseed, and galleta.

Broadleafed Forbs

The widest selection of forbs exists in the mountain browse location. Species found to have excellent adaptability include: Rocky mountain penstemon, bouncing-bet, arrowleaf balsamroot, Lewis flax, and sweetanise. The forb mixture rows also did very well on this site.

Gooseberryleaf globemallow, Pacific aster, Palmer penstemon, and small burnet showed intermediately adaptable growth characteristics on the mountain browse location.

One species found to be poorly adapted to this location was verbena. This species should be left out of this type in future reclamation work.

Leguminous Forbs

The legumes did very well on this site. Excellent leguminous forbs include a good variety of vetch, alfalfa and lupine species. Among these are: Lutana cicer milkvetch, Penngift crownvetch, Utah sweetvetch, rambler alfalfa, rhizoma alfalfa, mountain lupine, and silky lupine. *Astragalus* species also did well on this site.

Sicklepod milkvetch was the only legume in the partially adaptable category. However, two legumes fell in the poorly adapted category. Both Madrid yellow sweetclover and purple prairie clover did poorly here.

Shrubs

Excellent shrub species included a good variety of species. Green ephedra did well as expected. Other good shrub species were: black chokecherry, yellowbrush, antelope bitterbrush, and Stansbury cliffrose. This site has the potential to support a diverse population of shrub species and this diversity should be included in a rehabilitation plan.

Partially adapted species include: black sagebrush, big sagebrush, rubber rabbitbrush, desert bitterbrush, common bladdersenna, winterfat, curl-leaf mountain mahogany, desert peachbrush, snowberry and serviceberry. These species should be used to fill gaps in the establishment of a diverse community.

Poorly adapted species included all the saltbushes: fourwing saltbush, shadscale saltbush, Gardner saltbush, and Nuttall saltbush. In addition, the following species were unacceptable: true mountain mahogany, Russian olive, skunkbush sumac, blueberry elder, silver buffaloberry, and winterberry.

Selected Species for Seeding

Again, if regulations warrant only native species, the following can be used: Critana thickspike wheatgrass, Sodar streambank wheatgrass, western wheatgrass, Barton western wheatgrass, Rosana western wheatgrass, C-43 basin wildrye, mountain brome, green needlegrass, slender wheatgrass, bluebunch wheatgrass and Arizona fescue.

Good native broadleafed forbs include Rocky mountain penstemon, arrowleaf balsamroot, Lewis flax, and sweetanise. Legumes to include would be Penngift crownvetch, Utah sweetvetch, and mountain lupine.

Native shrub species that could be used are: black chokecherry, yellowbrush, antelope bitterbrush, green ephedra, and Stansbury cliffrose which all show good rehabilitation promise.

Both native and introduced species can be picked from the well adapted category of grasses, broadleafed forbs, leguminous forbs, and shrubs. A good community of diverse vegetation can be established from this list.

Possible Reasons for Seedling Failures

The cause and effect of many factors is responsible for seedling failure on the four sites. No single factor is wholly responsible for the poor results shown by certain seeded species.

Undoubtedly, invasion by annual and perennial plants caused competition for moisture and nutrients with the seeded species. With this invasion, the vigor, emergence and overall growth of seeded species was retarded or eliminated.

The problem of species adaptability was linked somewhat to the site on which they were planted. Varying factors such as elevation, climate, soil types and differences, low precipitation, and a highly variable precipitation pattern accounted for problems in seedling establishment.

Other factors contributing to poor seedling emergence are loss to herbivores by grazing and burrowing, loss of seed to birds and rodents, seeding at the wrong season of the year, attack of fungi and disease organism on the young seeds, winter kill of the fall seedlings, seed rot from excessive moisture availability, surface soil crusting and improper seeding depth.

Table 1 summarizes the emergence and survival of the best adapted species at each study site. Each number is an average for both plowing and scraping and favorable and unfavorable sites.

Natural Recovery

The abilities of the four vegetation types to revegetate themselves by natural methods was measured with data collected and interpreted over a four year period from 1973 to 1976. Trends in species dominants and relative length of time to return to pre-disturbance associations were sought. The problem in interpreting secondary successional stages was amplified by the amount of time between each successional stage. It was hoped that by integrating these initial successional stages a plan could be developed for coupling both artificial and natural revegetation in future semi-arid rehabilitation schemes.

By understanding these secondary successional stages, one can use them as an aid in reducing immediate soil loss and establish an adequate base to begin the return of disturbed lands to their former productivity.

Since no herbicides were used on these treatments, the observations represent an unaided (by man) attempt at establishment by seeded vegetation. Also, by deleting the use of a herbicide, the natural vegetation was not impeded from recolonizing the area and directly competing with the seeded varieties. Thus, with the use of herbicides, fertilization, and irrigation the results of this experiment could be quite different.

The natural recovery zones occupied the middle one third of each study location. Each of these zones were plowed and scraped to remove existing vegetation, as were the seeded areas, in the summer of 1972.

Table 1. Summary table of yearly stand establishment and survival averages for the grasses, forbs, and shrubs seeded on the four study locations subjected to both plowing and scraping, and favorable and unfavorable conditions. Data collected in 1975 and 1976.

Species	Treatments							
	Sagebrush		Low Pinyon-Juniper		High Pinyon-Juniper		Mountain browse	
	1975	1976	1975	1976	1975	1976	1975	1976
Grasses								
Critana thickspike wheatgrass	2.7	2.5	2.3	2.1	2.1	1.7	3.4	3.2
Siberian wheatgrass	2.9	3.3	2.6	2.2	2.8	2.9	3.6	3.4
Amur intermediate wheatgrass	2.5	2.4	2.8	2.6	2.6	3.0	3.4	3.6
Oahe intermediate wheatgrass	2.8	2.4	2.8	2.7	2.9	2.7	3.4	3.5
Nordan crested wheatgrass	3.0	3.1	2.7	2.6	3.1	3.0	3.3	3.3
Sodar streambank wheatgrass	2.5	2.6	2.7	2.6	2.0	-	3.5	3.2
Luna pubescent wheatgrass	2.6	2.8	2.8	3.0	2.8	3.2	3.6	3.9
Rosana western wheatgrass	2.1	-	2.3	2.0	2.4	2.1	3.1	3.1
Slender wheatgrass	-	-	2.5	2.2	-	-	3.3	2.7
Bluebunch wheatgrass	-	-	1.5	2.2	-	-	3.4	3.3
Jose tall wheatgrass	2.2	1.7	-	-	2.4	2.0	2.8	2.4
Barton western wheatgrass	-	-	-	-	-	-	2.7	2.6
C-30 western wheatgrass	-	-	-	-	-	-	2.8	2.5
Regar meadow brome	2.8	2.9	2.8	3.1	2.6	2.4	3.5	3.6
Manchar brome	-	-	1.9	2.0	2.2	1.9	3.2	3.3
Mountain brome	2.3	2.5	-	-	2.6	2.5	3.7	3.7
Sawki Russian wildrye	2.2	1.8	2.1	2.1	-	-	2.8	2.6
C-43 basin wildrye	-	-	-	-	-	-	2.7	2.7
Shermans big bluegrass	-	-	-	-	-	-	-	-
Green needlegrass	2.1	2.2	1.8	1.9	2.6	2.3	3.2	3.2
Durar hard fescue	-	-	-	-	2.3	1.8	3.1	3.0
Phleum pratense	-	-	1.5	1.7	-	-	2.2	2.2
Indian ricegrass	-	-	-	-	2.1	1.9	-	-
Forbs								
Lewis flax	2.9	2.4	2.8	2.3	1.9	2.0	2.4	2.6
Arrowleaf balsamroot	1.7	-	2.4	2.3	3.2	3.0	3.2	2.9
Penngift crownvetch	-	-	2.9	2.8	-	-	2.8	2.6
Astragalus spp.	2.5	1.5	3.2	2.4	-	-	2.3	1.7
Utah sweetvetch	2.2	-	-	-	2.3	1.6	2.3	2.1
Lutana ciser milkvetch	-	-	-	-	-	-	2.5	2.1
Sicklepod milkvetch	-	-	2.4	1.9	-	-	-	-
Mixture	2.3	-	-	-	-	-	2.9	2.5
Rambler alfalfa	2.3	-	3.2	2.8	1.9	1.4	2.4	2.3
Rhizoma alfalfa	2.4	-	2.4	2.1	2.1	1.8	2.4	2.4
Small burnet	-	-	2.3	2.1	1.8	-	-	-
Gooseberryleaf globemallow	2.0	1.8	2.5	2.1	2.1	2.0	-	-
Palmer penstemon	2.2	1.5	-	-	2.5	1.8	1.9	-
Rocky mountain penstemon	-	-	-	-	2.0	-	2.9	2.4
Bouncing-bet	-	-	-	-	2.2	-	2.8	2.3
Sweetanise	-	-	-	-	-	-	2.5	1.8
Verbena	-	-	-	-	2.4	-	-	-
Madrid yellow sweetclover	1.7	1.0	2.0	1.5	-	-	-	-
Mountain lupine	-	-	-	-	-	-	1.8	-
Silky lupine	-	-	-	-	-	-	2.0	1.4
Shrubs								
Green ephedra	2.3	2.4	2.9	2.5	2.0	1.4	2.3	2.2
Antelope bitterbrush	2.2	1.9	-	-	2.4	1.7	2.9	2.7
Desert bitterbrush	-	-	-	-	1.8	-	-	-
Stansbury cliffrose	1.8	1.9	-	-	2.3	1.3	1.6	1.3
Winterfat	2.6	2.2	1.4	1.8	1.8	-	-	-
Shadscale saltbush	2.0	2.0	-	-	-	-	-	-
Yellowbrush	2.7	3.0	2.1	1.5	2.2	1.5	1.9	1.3
Black chokecherry	-	-	-	-	-	-	1.7	-
Common bladdersenna	-	-	-	-	2.1	1.6	-	-

The four natural recovery areas were sampled in their present associations and compared with both the 1973 area associations and those found in the control. The invasion was also sampled in the seeded row areas and relationships were drawn between these values and those of the natural recovery zones.

Mid-Elevation Sagebrush Location

The number of grasses, forbs, and shrubs on the natural recovery portion of this site have shown significant increases in both numbers of species and percent total cover since the initial sampling period during the summer of 1973 (Table 2). The number of species identified in 1973 roughly doubled by 1976 and in most cases the 1976 figures equalled the number of species present on the control zones. There appeared to be no significant difference in species numbers between the scraped and plowed treatments applied to the natural recovery zones in 1972.

The percent total cover values recorded in 1973 had also increased by 1976. Of the two treatments, the plowed expressions showed higher cover values than the scraped expressions on both the 1973 and 1976 samplings. The 1976 sampling exhibited similar cover values of grasses and forbs with those recorded in the control. However, the total cover values of the shrub species on the natural recovery zones were much less than those on the control locations. Only little rabbitbrush exhibited any significant percentage of the total cover value.

The dominant plant associations on the natural recovery areas of the mid-elevation sagebrush location currently contain Indian ricegrass (*Oryzopsis hymenoides*), needle-and-thread (*Stipa comata*), white gilia (*Gilia congesta*), and little rabbitbrush (*Chrysothamnus viscidiflorus*).

The variety of plants recorded (Table 2) shows an increasing diversity compared to the first sampling conducted in 1973. In 1973 the dominant plant associations were western wheatgrass (*Agropyron smithii*), buckwheat (*Eriogonum spp.*), scarlet globemallow (*Sphaeralcea coccinea*), and winterfat (*Eurotia lanata*). The 1973 sampling shows (Table 2) a large number of pioneer plants such as Russian thistle (*Salsola iberica*), stickseed (*Lappula redowski*), scarlet globemallow, and cheatgrass (*Bromus tectorum*), while the 1976 sampling exhibits a return (with the exception of shrubs) to pre-disturbance plant numbers and associations.

The seeded rows were also invaded by native and introduced plant species. These areas were sampled in 1975 and 1976 to measure the success and persistence of the seeded varieties (Appendix, Tables 5 & 6). It became evident that though the seeded species were enduring on this location, the invading species exhibited large success in establishing themselves and competing equally with the seeded species. It was interesting to note that the invading species generally had higher percent cover values and seem to be on the increase with each successive season.

The major plant associations in the control areas largely consist of big sagebrush (*Artemisia tridentata*), needle-and-thread grass, and goldenweed (*Haplopappus nuttallii*). Both the natural recovery areas and the seeded areas contained a relatively small number of shrub species.

Low Pinyon-Juniper Location

Of the four study locations, this site possessed the fewest number of grass species. Indian ricegrass and slender wheatgrass were the most frequent in both 1973 and 1976 (Table 3). With the exception of trace

Table 2. Percent frequency and percent total cover of species re-invading natural recovery areas on the mid-elevation sagebrush location. Data collected in July of 1973 and 1976.

Species	Frequency					Total Cover				
		Plowed		Scraped			Plowed		Scraped	
	Control	1973	1976	1973	1976	Control	1973	1976	1973	1976
Grasses										
Oryzopsis hymenoides	.24	.42	.65	.17	.39	.02	.02	.07	.01	.04
Stipa comata	.39	.02	.50	.06	.23	.03	T	.06	.01	.03
Agropyron smithii	.21	.26	.15	.33	.45	.01	.02	.01	.02	.03
Koelerla gracillis	.18	-	.15	-	.14	.01	-	.02	-	.01
Agropyron trachycaulum	.11	-	-	-	-	.01	-	-	-	-
Bromus tectorum	.02	-	.11	-	T	T	-	.003	-	T
Sitanion longifolium	.05	-	.02	-	T	.004	-	T	-	T
Poa secunda	.11	-	T	-	.03	.003	-	T	-	.001
Carex spp.	.26	-	.24	-	.15	.02	-	.01	-	.004
Forbs										
Sphaeralcea coccinea	.26	.12	.41	.30	.39	.01	.03	.03	.03	.01
Haplopappus nuttallll	.33	.02	.18	.14	.23	.02	T	.02	.01	.01
Eriogonum spp.	.14	.14	.18	.18	.14	.01	.04	.02	.03	.01
Gilia congesta	.21	-	.08	-	.18	.01	-	.01	-	.02
Phlox hoodii	.20	.05	.09	.15	.24	.01	.002	.002	.01	.02
Salsola iberica	-	.14	-	.10	-	-	.02	-	.01	-
Astragalus purshii	.06	.21	.06	.15	.12	.003	.02	.002	.01	.003
Penstemon spp.	.05	-	.12	-	.15	.003	-	.01	-	.01
Euphorbia robusta	.05	-	.08	-	.02	.01	-	.01	-	.002
Lappula redowskii	-	.05	-	.05	-	-	.01	-	.01	-
Chenopodium fremontii	.02	.08	.03	.03	T	T	.01	.001	.004	T
Mustard spp.	-	.05	.02	.03	.05	-	.01	.002	.004	.002
Allium textile	.02	.06	.02	.21	.08	T	.003	T	.01	.003
Eriogonum umbellatum	-	-	.15	-	.06	-	-	.01	-	.002
Lomatium greyi	-	.14	.02	-	T	-	.01	T	-	T
Physaria floribunda	-	.11	.02	.08	.05	-	.003	T	.002	.001
Chaenactis douglasii	-	-	.06	.06	.03	-	-	.002	.004	.001
Phlox longifolia	.08	-	.09	-	.09	.002	-	.004	-	.004
Aster canescens	-	-	.05	.03	T	-	-	.003	.003	T
Hedysarum boreale	-	-	.02	-	.03	-	-	T	-	.004
Erigeron eatonii	.09	-	.02	-	.02	.002	-	T	-	T
Antennaria rosea	.02	-	-	-	-	.002	-	-	-	-
Aster arenosus	.03	-	-	-	-	.001	-	-	-	-
Senecio multilobatus	.03	-	-	-	-	.001	-	-	-	-
Townsendia incana	.03	-	-	-	-	.001	-	-	-	-
Cryptantha sericea	.02	-	.02	-	T	T	-	T	-	T
Hymenoxys richarsonii	.02	-	.03	-	.02	T	-	.001	-	T
Shrubs										
Artemisia tridentata	.26	-	.02	-	T	.10	-	T	-	T
Chrysothamnus viscidiflorus	.09	.02	.06	.08	.20	.02	T	.01	.01	.03
Leptodactylon pungens	.05	-	T	-	.03	.02	-	T	-	.001
Tetradymia spp.	.02	-	.02	-	.06	.002	-	.002	-	.01
Eurotia lanata	.02	.02	.02	.10	.02	.005	.01	.01	.01	.001
Artemisia frigida	.03	-	.02	-	.02	.001	-	T	-	T
Opuntia spp.	.02	.02	.02	.10	.02	T	.01	.002	.01	T

Table 3 Percent frequency and percent total cover of species re-invading natural recovery areas on the low elevation pinyon-juniper location. Data collected in July of 1973 and 1976.

Species	Frequency					Total Cover				
		Plowed		Scraped			Plowed		Scraped	
	Control	1973	1976	1973	1976	Control	1973	1976	1973	1976
Grasses										
Oryzopsis hymenoides	.25	.29	.51	.34	.52	.03	.01	.05	.02	.06
Agropyron trachycaulum	.27	-	.18	.02	.23	.03	-	.03	.002	.04
Carex spp.	-	-	.01	-	-	-	-	T	-	-
Forbs										
Haplopappus nuttallii	.42	.13	.37	.22	.44	.02	.01	.02	.02	.03
Linum lewisii	.09	.14	.27	.09	.14	.01	.004	.02	.004	.03
Haplopappus acaulis	.26	-	.07	-	.15	.02	-	.004	-	.01
Phlox hoodii	.35	-	.09	-	.18	.02	-	.004	-	.01
Oenothera spp.	.05	-	.03	-	.06	.003	-	.001	-	.002
Penstemon teucriodes	.26	-	.15	-	.23	.01	-	.01	-	.01
Hymenoxys richardsonii	.11	-	.04	-	.06	.01	-	.01	-	.01
Mentzelia spp.	-	-	-	-	.04	-	-	-	-	.02
Aster arenosus	.12	-	.08	-	.11	.003	-	.01	-	.01
Mentha arvensis	.03	-	.16	-	.15	.001	-	.01	-	.01
Euphorbia robusta	.02	-	.09	-	.06	T	-	.01	-	.004
Physaria floribunda	.03	-	.01	-	.01	.001	-	T	-	T
Gilia congesta	-	-	.08	-	.12	-	-	.004	-	.01
Salsola iberica	.04	-	.08	-	.04	.003	-	.004	-	.002
Streptanthus cordatus	.05	-	.04	-	.04	.004	-	.001	-	.001
Circium spp.	-	-	.03	-	.01	-	-	.004	-	.001
Chenopodium fremontii	-	.03	-	.02	-	-	.001	-	.002	-
Taraxacum officinale	-	.03	-	.02	-	-	.002	-	.001	-
Eriogonum alatum	.02	-	-	-	-	.002	-	-	-	-
Arenaria eastwoodiae	-	-	.04	-	.04	-	-	.001	-	.001
Erigeron eatonii	.03	-	-	-	-	.001	-	-	-	-
Mustard spp.	-	.04	-	-	-	-	.001	-	-	-
Sphaeralcea coccinea	-	.01	-	.01	-	-	T	-	T	-
Cryptantha sericea	.01	-	-	-	-	T	-	-	-	-
Crepis spp.	.01	-	-	-	-	T	-	-	-	-
Comandra umbellata	.02	-	.01	-	-	T	-	T	-	-
Shrubs										
Chrysothamnus viscidiflorus	.06	-	.26	.01	.25	.003	-	.03	T	.03
Eurotia lanata	.06	.03	.02	.02	.03	.01	.01	.01	.003	.01
Cercocarpus montanus	.10	-	.01	.01	.01	.01	-	.004	.002	.002
Amelanchier alnifolia	.03	.01	-	.03	.01	.01	.01	-	.01	.004
Symphoricarpos oreophilus	.02	-	-	-	-	.002	-	-	-	-
Tetradymia spp.	-	.01	-	-	-	-	T	-	-	-
Trees										
Pinus edulis	.01	-	-	-	-	.002	-	-	-	-

amounts of sedge in the control zone, the number of grasses identified on the natural recovery areas in 1976 was identical to the number found on the control zones. The number of forbs collected in 1973 approximately tripled by 1976 and is very close to the numbers found on the adjacent control zone. The 1976 and 1973 samplings exhibited a shrub understory similar to the control in numbers present, but failed to exhibit any significant overstory recovery to date. Species numbers did not seem to be affected by either plowing or scraping treatments.

Data collected in 1976 revealed much higher percent total cover values than those recorded in 1973. The scraped treatments seemed to have higher cover values than those collected on the plowed portions in both 1976 and 1973. The grass and forb cover values in 1976 either equalled or were higher than those found in the control (both plowed and scraped expressions). However, the shrub cover values on the control portions exhibited more uniform values than either the plowed or scraped treatments. Both understory and overstory on the plowed and scraped treatments lack the cover values found on the control for the dominant shrubs and trees.

The natural recovery areas of the low pinyon-juniper location presently contain an Indian ricegrass, Lewis flax (*Linum lewisii*), goldenweed, and little rabbitbrush plant association. The same area sampled in 1973 (Table 3), exhibited a similar plant association of Indian ricegrass, goldenweed, and serviceberry (*Amelanchier alnifolia*). Changes between the 1973 and 1976 sampling are evident by comparing tabled results. The 1973 sampling exhibited a lower diversity of plant species, but not as significant a difference as those recorded between years on the other three locations.

The seeded areas showed an increase in species invasion from 1975 to 1976. As with the sagebrush location, total cover values of the planted species were lower on the whole than the invading ones (Appendix, Tables 7 & 8). In contrast with the sagebrush location, the seeded species on both the 1972 and 1973 seedings exhibited much better growth and vigor than the more aggressive invading species. The species associations in the seeded areas were similar to those sampled in the natural recovery sites.

On the control locations, the major plant associations were slender wheatgrass (*Agropyron trachycaulum*), Indian ricegrass, stemless goldenweed (*Haplopappus acaulis*), mountain mahogany (*Cercocarpus montanus*), and serviceberry association. The overstory was composed of pinyon pine (*Pinus edulis*) and juniper (*Juniperus spp.*).

High Elevation Pinyon-Juniper Location

Significant increases in both numbers of species present and percent total cover have occurred on this site since the initial sampling period of 1973 (Table 4). The number of grasses, forbs, and shrubs identified in 1973 had about doubled by 1976. These 1976 figures were approximately equal to those recorded in the control zones. The natural recovery zones exhibited no significant differences in species numbers between the scraped and plowed treatments.

The values recorded in 1973 for percent total cover had increased as well by 1976. Neither the plowed or scraped treatments showed any particular differences in cover values. The values were very close between the treatments for both the 1973 and 1976 samplings. The 1976 cover values were higher than the control estimates for the grasses and forbs. However,

Table 4 Percent frequency and percent total cover of species re-invading natural recovery areas on the high pinyon-juniper location. Data collected in July of 1973 & 1976.

Species	Frequency					Total Cover				
		Plowed		Scraped			Plowed		Scraped	
	Control	1973	1976	1973	1976	Control	1973	1976	1973	1976
Grasses										
Oryzopsis hymenoides	.48	.50	.83	.55	.83	.05	.03	.20	.05	.19
Agropyron smithii	.42	-	.29	-	.18	.04	-	.03	-	.02
Agropyron spp.	-	.09	-	.24	-	-	.02	-	.04	-
Bromus tectorum	.30	.36	.48	.18	.45	.01	.05	.02	.03	.01
Agropyron trachycaulum	.14	-	-	-	.05	.02	-	-	-	.02
Koeleria gracillis	.03	.02	.06	.02	.02	.004	.004	.01	T	.002
Carex spp.	.08	-	.03	-	.11	.01	-	.001	-	.003
Sitanion longifolium	.12	.07	.03	.06	.06	.01	.01	.003	.003	.01
Stipa comata	.09	-	-	-	.02	.01	-	-	-	.006
Poa secunda	.02	-	.06	-	.02	T	-	.002	-	T
Forbs										
Aster canescens	.26	-	.56	-	.45	.01	-	.02	-	.02
Balsamorhiza sagittata	-	-	.05	.02	.05	-	-	.01	.004	.02
Agoseris glauca	-	.08	-	.08	-	-	.01	-	.01	-
Haplopappus nuttallii	.09	-	-	-	.15	.01	-	-	-	.03
Astragalus purshii	.05	-	.03	.08	.11	.001	-	.002	.002	.03
Chaenactis douglasii	.15	.33	.14	.18	.11	.01	.03	.005	.01	.003
Oenothera spp.	.02	-	-	-	-	.01	-	-	-	-
Phlox hoodii	.03	-	.03	-	.03	.003	-	.001	-	.004
Crepis spp.	-	.03	.02	.03	.05	-	.003	.002	.01	.004
Gilia aggregata	-	-	.08	-	-	.01	-	-	-	-
Physaria floribunda	.12	.17	.08	.29	.06	.003	.004	.002	.01	.002
Chenopodium fremontii	.03	.29	-	.18	.06	.003	.03	-	.02	.002
Lathyrus leucanthus	-	-	-	.02	-	-	-	-	.002	-
Sphaeralcea coccinea	.03	-	.02	-	-	.003	-	T	-	-
Cryptantha sericea	.05	-	.03	.02	-	.003	-	.001	T	-
Circium spp.	-	-	.03	-	-	-	-	.003	-	-
Lappula redowskii	-	.30	.06	.11	.03	-	.05	.002	.01	.001
Achillea lanulosa	-	-	-	.03	-	-	-	-	.001	-
Phlox longifolia	.09	-	-	-	-	.002	-	-	-	-
Salsola iberica	.02	-	-	-	-	.002	-	-	-	-
Senecio multilobatus	.06	-	-	-	-	.002	-	-	-	-
Sisymbrium altissimum	.02	-	-	-	-	T	-	-	-	-
Townsendia incana	.02	-	-	-	-	T	-	-	-	-
Mustard spp.	-	.18	.02	.20	-	-	.04	T	.02	-
Descurainia sophia	.02	-	-	-	-	T	-	-	-	-
Shrubs										
Symphoricarpos orcophilus	.05	-	.03	-	.09	.02	-	.01	-	.002
Chrysothamnus viscidiflorus	.03	.09	.15	.03	.03	.01	.02	.01	.001	.003
Artemisia tridentata	.02	-	-	-	.02	.01	-	-	-	.002
Amelanchier alnifolia	.05	-	-	.02	-	.01	-	-	.002	-
Purshia tridentata	.06	-	-	-	-	.01	-	-	-	-
Chrysothamnus nauseosus	-	.02	.05	-	.02	-	.004	.01	-	.01
Artemisia ludoviciana	-	-	-	-	.02	-	-	-	-	T
Trees										
Pinus edulis	.02	-	-	-	-	.002	-	-	-	-

the control zone exhibited much higher cover values for shrubs than the 1976 or 1973 samplings.

An Indian ricegrass, goldenweed, snowberry (*Symphoricarpos oreophilus*), and little rabbitbrush plant association is presently evidenced on the natural recovery zone of the high pinyon-juniper location (Table 4). These sites are very heavily invaded with Indian ricegrass and cheatgrass (*Bromus tectorum*). The plant associations in 1973 (Table 4) were Indian ricegrass, stickseed, Mustard species, and little rabbitbrush. This first sampling showed much less diversity (one half as great) than subsequent samplings in 1975 and 1976. A much greater percentage of annuals were present with fewer grasses and shrubs. Natural recovery areas on the high pinyon-juniper site are recovering much faster than on the sagebrush and low pinyon-juniper locations. However, the invasion on the high pinyon-juniper is much higher and, in some instances, as great as that observed on the higher mountain browse location.

Following the trend on the previous two sites, the invading species have much higher total cover percentages than the seeded varieties (Appendix, Tables 9 & 10). Due to excessive natural reinvasion, the seeded species have suffered greatly in competitive areas, especially in moisture relations. The 1973 seeding was particularly effected. The seeded species only compose one tenth the total cover value of the more aggressive invading species.

The control areas exhibited an Indian ricegrass, hoary aster (*Aster canescens*), snowberry, rabbitbrush (*C. nauseosus* and *C. viscidiflorus*), serviceberry, and antelope bitterbrush (*Purshia tridentata*) plant association. The evidence of multiple shrub dominants is the common condition in the control zones. There are no pinyon or juniper trees present on

site due to past chaining procedures. The natural recovery areas have a large species diversity but low overall total cover values (due to extensive invasion by Indian ricegrass). Shrub reestablishment is in evidence, but recovery is still quite slow.

Mountain Browse Location

As witnessed on the previous three locations, the number of species present and the percent total cover values increased from 1973 to 1976 (Table 5). The greatest increase in species numbers occurred between the 1973 and 1976 grass samplings. The forbs and shrubs showed increases from 1973 to 1976, but not as great a difference as evidenced in the other three study locations. The control data and the 1976 sampling data were roughly equal in species numbers. There appeared to be no difference in species numbers between the plowed and scraped treatments.

The percent total cover values showed very significant increases between the 1973 and 1976 samplings. There were no large differences in cover values between the plowed and scraped treatments. The control zones exhibited lower cover values for grasses and forbs than the 1976 sampling. Higher cover values for shrubs were shown by the control areas than the 1976 sampling, but reestablishment on these disturbed areas is occurring at a moderate pace and is the least susceptible to the long term management problems of soil loss and decreased productivity.

The dominant plant associations on the natural recovery areas of the mountain browse location are slender wheatgrass, lupine (*Lupinus spp.*), little rabbitbrush, and serviceberry. A much greater diversity was evident between the 1976 (Table 5) and the 1973 samplings. Lupine has invaded this site very heavily and is the predominant plant species on the location.

Table 5, Percent frequency and percent total cover of species re-invading natural recovery areas on the mountain browse location. Data collected in July of 1973 & 1976.

Species	Frequency					Total Cover				
		Plowed		Scraped			Plowed		Scraped	
	Control	1973	1976	1973	76	Control	1973	1976	1973	1976
Grasses										
Agropyron trachycaulum	-	-	.30	-	.53	-	-	.03	-	.06
Oryzopsis hymenoides	-	-	-	-	.20	-	-	-	-	.03
Bromus spp.	-	.11	-	-	-	-	.01	-	-	-
Poa fendleriana	.20	-	.09	-	.09	.02	-	.004	-	.01
Agropyron smithii	.41	-	.02	-	-	.02	-	.002	-	-
Agropyron spicatum	.24	-	.02	-	-	.01	-	T	-	-
Stipa lettermani	.09	-	.02	-	.02	.01	-	.002	-	T
Sitanion longifolium	-	-	-	-	.06	-	-	-	-	.01
Agropyron spp.	-	.05	-	.21	-	-	.003	-	.01	-
Koeleria gracillis	-	-	.03	-	.03	-	-	.003	-	.003
Stipa comata	-	-	-	-	.03	-	-	-	-	.003
Poa fendleriana	-	-	-	.02	-	-	-	-	.002	-
Hordeum jubatum	-	-	.02	-	-	-	-	.002	-	-
Bromus marginatus	.02	-	-	-	-	T	-	-	-	-
Poa secunda	.02	-	-	-	-	T	-	-	-	-
Carex spp.	.02	-	.02	-	.02	T	-	T	-	T
Bromus tectorum	.02	-	.02	-	.02	T	-	T	-	T
Forbs										
Lupinus spp.	.50	.47	.77	.55	.61	.04	.08	.14	.10	.08
Astragalus miser	.36	.09	.23	.05	.09	.03	.004	.03	.003	.01
Amaranthus spp.	.08	-	.86	-	.64	.002	-	.03	-	.02
Penstemon teucroides	.06	-	.18	-	.35	.003	-	.01	-	.02
Balsamorhiza sagittata	.08	.06	.08	.09	.12	.02	.002	.02	.01	.02
Phlox multiflora	.18	-	.14	-	.27	.01	-	.01	-	.02
Salsola iberica	-	.05	-	.14	-	-	.01	-	.01	-
Erigeron eatonii	.14	-	.12	.02	.20	.01	-	.01	T	.01
Collomia linearis	.09	-	.35	-	.21	.002	-	.01	-	.01
Chenopodium fremontii	-	.14	.29	.11	.20	-	.02	.01	.01	.01
Phlox longifolia	.14	-	.18	-	.32	.01	-	.004	-	.01
Comandra umbellata	.20	-	.06	-	.23	.01	-	.002	-	.01
Wyethia amplexicaulis	-	.06	-	.05	-	-	.01	-	.001	-
Crepis spp.	.03	.17	.12	.10	.05	.001	.01	.01	.004	.001
Castilleja spp.	.06	.03	-	.08	-	.01	.003	-	.01	-
Eriogonum umbellatum	.24	.02	.03	.02	.03	.02	T	.003	.002	.003
Linum lewisii	-	.03	-	-	-	-	.003	-	-	-
Penstemon spp.	.03	.02	.06	.08	.02	.001	T	.004	.01	.002
Phlox spp.	-	.09	-	.14	-	-	.002	-	.01	-
Trifolium gymnocarpon	.09	-	.06	-	.02	.002	-	.002	-	T
Agoseris glauca	.02	.05	.05	.02	.02	T	.001	.001	T	T
Sphaeralcea coccinea	.03	.02	.02	.02	.02	.001	.002	T	T	.002
Hedysarum richardsonii	-	-	-	-	.02	-	-	-	-	.002
Eriogonum alatum	.02	-	.02	-	-	.001	-	T	-	-
Aster canescens	-	-	.05	-	-	-	-	.001	-	-
Chaenactis douglasii	-	-	-	.02	.03	-	-	-	T	.001
Tragopogon dubius	-	-	-	.02	-	-	-	-	T	-
Lathyrus leucanthus	.05	.18	-	.09	.02	.001	.01	-	.004	T
Lactuca serriola	.05	-	-	-	-	.001	-	-	-	-
Allium textile	-	.02	.02	.02	.02	-	T	T	.001	T
Delphinium spp.	.02	-	-	-	-	T	-	-	-	-
Shrubs										
Purshia tridentata	.39	-	.03	.11	.08	.09	-	.001	.01	.004
Amelanchier alnifolia	.15	.08	.29	.12	.20	.05	.004	.05	.01	.05
Chrysothamnus viscidiflorus	.12	.12	.35	.14	.24	.01	.02	.06	.02	.05
Artemisia tridentata	.30	.03	.20	.06	.11	.05	.001	.03	.004	.03
Symphoricarpos oreophilus	.26	.03	.11	.17	.11	.05	.001	.01	.01	.01
Tetradymia spp.	.02	.02	.05	-	.09	.002	.002	.02	-	.03

The plant associations of the 1973 sampling were various wheatgrass species, lupine, and little rabbitbrush. As would be expected, the biomass and diversity has greatly increased from 1973 to 1976. Also, the amount of natural re-invasion coupled with the highest success rates of seeded species, make this site the most productive of all four locations.

Though this site has the greatest invasion on both recovery and seeded sites, the seeded species have responded surprisingly well. The planted rows exhibit the greatest growth, vigor and persistence of any site planted. The same observations collected on the previous three locations hold true on the mountain browse site. The planted species again comprise lower total cover values than the invading species (roughly one third as much) (Appendix, Tables 11 & 12). The potential for integrating both natural and artificial revegetation with positive results is the most promising on this site. This is not as true on the lower sites where moisture is less and competition is more pronounced.

The major plant associations of the control areas were antelope bitterbrush, serviceberry, snowberry, big sagebrush (*Artemisia tridentata*), muttongrass (*Poa fendleriana*), western wheatgrass (*Agropyron smithii*), lupine, and horn locoweed (*Astragalus miser*). Multiple shrub dominants comprised the overstory of the study area and represented the major growth form.

SUMMARY

Species showing the best adaptability on the sagebrush location included: Oahe and Amur intermediate wheatgrass, Critana thickspike wheatgrass, Rosana western wheatgrass, Siberian wheatgrass, Nordan crested wheatgrass, Luna pubescent wheatgrass, Sodar streambank wheatgrass, Jose tall wheatgrass, Regar meadow brome, mountain brome, Sawki Russian wildrye, green needlegrass, arrowleaf balsamroot, Palmer penstemon, Lewis flax, gooseberryleaf globemallow, Penngift crownvetch, Utah sweetvetch, Astragalus species, mixture (a 1973 seeding of a variety of broadleafed forbs and legumes including an *Astragalus* species, a *Penstemon* species and purple prairie clover), green ephedra, yellowbrush, winterfat, Stansbury cliffrose, antelope bitterbrush, and shadscale saltbush.

On the low pinyon-juniper site, the species showing the best characteristics were: Oahe and Amur intermediate wheatgrass, Nordan crested wheatgrass, Critana thickspike wheatgrass, Sodar streambank wheatgrass Siberian wheatgrass, Rosana western wheatgrass, Luna pubescent wheatgrass, slender wheatgrass, bluebunch wheatgrass, Regar meadow brome, Manchar brome, Sawki Russian wildrye, green needlegrass, Timothy, Lewis flax, small burnet, gooseberryleaf globemallow, Madrid yellow sweetclover, arrowleaf balsamroot, sicklepod milkvetch, Penngift crownvetch, Astragalus species, rambler and rhizoma alfalfa, yellowbrush, winterfat, and green ephedra.

The high pinyon-juniper location contained a wide variety of adaptable species such as: Oahe and Amur intermediate wheatgrass, Nordan crested wheatgrass, Jose tall wheatgrass, Rosana western wheatgrass, Sodar streambank wheatgrass, Siberian wheatgrass, Luna pubescent

wheatgrass, Critana thickspike wheatgrass, Regar meadow brome, mountain brome, Manchar brome, green needlegrass, Durar hard fescue, Indian ricegrass, bouncing-bet, small burnet, Lewis flax, Palmer penstemon, Rocky Mountain penstemon, gooseberryleaf globemallow, verbena, arrowleaf balsamroot, Utah sweetvetch, rambler alfalfa, rhizoma alfalfa, green ephedra, yellowbrush, antelope bitterbrush, Stansbury cliffrose, desert bitterbrush, and common bladdersenna.

The mountain browse location contains the greatest percent of adapted species. They include: Oahe and Amur intermediate wheatgrass, Nordan crested wheatgrass, Critana thickspike wheatgrass, Jose tall wheatgrass, Rosana western wheatgrass, Sodar streambank wheatgrass, Barton western wheatgrass, slender wheatgrass, bluebunch wheatgrass, Luna pubescent wheatgrass, mountain brome, Regar meadow brome, Manchar brome, C-43 basin wildrye, Sawki Russian wildrye, Durar hard fescue, Arizona fescue, green needlegrass, Timothy, Rocky mountain penstemon, bouncing-bet, arrowleaf balsamroot, Lewis flax, sweetanise, mixture, Lutana cicer milkvetch, Penngift crownvetch, Utah sweetvetch, rambler alfalfa, rhizoma alfalfa, mountain lupine, silky lupine, Astragalus species, green ephedra, black chokecherry, yellowbrush, antelope bitterbrush, and Stansbury cliffrose.

It should be added that species selected for use are coupled with the knowledge that results are directly related to the amount of moisture the sites receive. In this respect, hot and dry years should be taken into account with wetter, cooler ones. Some of the species lost vigor in the hotter, drier 1976 sampling period, but were otherwise quite vigorous in a more normal year such as 1975. It should be mentioned that

even with this apparent loss of vigor, the species still exhibited the desired characteristics to include them in a revegetation plan.

CONCLUSIONS AND IMPLICATIONS

The initial scope of this research was to test the applicability of the 81 seeded species in future semi-arid revegetation attempts. It was hoped that results would indicate a desirable set of species to seed on a disturbed landscape. The well adapted species mentioned have the necessary qualifications to serve as components in a revegetation scheme. They exhibit the needed emergence and vigor requirements to insure their survival and competitiveness with invading native vegetation. However, these tests do not indicate how the various plants would react in mixtures. Future work with mixtures and their interaction through secondary succession is needed to establish the final adaptability of tested species.

Because of the limited amount of disturbance on the seeded sites, further testing will be needed on more severe disturbances. Also, the use of mulches, fertilizers, herbicides, pesticides, and irrigation could also be incorporated which would alter the response of each species. However, species adaptability studies should be one of the first tests to be conducted in areas of proposed land disturbance of a significant nature. This study has met this criteria and has provided valuable information that should be utilized in future revegetation work in the Piceance Basin.

The trends observed on the natural recovery areas also shed light on other aspects of land rehabilitation. Results show that this method is slow in the Piceance Basin, but that the secondary successional stages do reduce soil erosion and provide a source of native forage to wild and domestic herbivores. Augmenting both natural and artificial revegetation (i.e. seeding native mixtures and allowing similar natives to invade and

complement the community) in a rehabilitation scheme, should serve as a guide in rapid establishment of a plant community to stabilize the soil. In such a mixture it is desirable to include nitrogen fixers (legumes), biennials, perennials, sod formers, rhizomatous species, and even the inclusion of unpalatable varieties. The function of the unpalatable species is to aid solely in soil stabilization. However, integrating seeded species with invading species can cause severe competition if moisture is the limiting factor. Other factors such as plant crowding, light requirements, soil nutrients, and durability (to grazing, trampling, etc.) among others, will also affect species success.

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APPENDIX

Table 1. Precipitation data (centimeters) collected at the Little Hills Experiment Station between January 1, 1971 and December 31, 1976.

	1971	1972	1973	1974	1975	1976
Jan.	1.8	1.1	2.2	3.1	2.0	1.2
Feb.	1.8	1.1	0.05	.04	1.3	1.9
March	2.5	0.8	3.1	3.9	3.1	4.2
April	2.5	3.7	4.3	5.7	4.0	3.0
May	4.0	3.6	3.3	0.2	5.9	4.9
June	0.2	2.5	3.4	3.5	4.4	4.1
July	0.6	2.3	5.1	3.5	7.6	2.7
Aug.	2.0	1.5	3.8	1.0	0.9	4.5
Sept.	3.5	2.9	4.1	0.8	1.8	3.1
Oct.	6.3	7.8	1.4	1.7	3.9	1.4
Nov.	2.5	2.8	4.9	0.8	1.9	0.3
Dec.	2.6	5.7	3.1	2.1	1.9	0.3
Totals	30.3	35.8	38.8	26.7	38.7	31.6

Table 2. Precipitation data (centimeters) collected on the four vegetation sites between May 30, 1975 and August 24, 1976.

Sites	6-30-75 to 6-10-76	5-30-75 to 6-30-75	6-30-75 to 7-30-75	7-30-75 to 8-13-75	5-16-76 to 6-12-76	6-12-76 to 7-21-76	7-21-76 to 8-24-76	7-30-75 to 7-23-76
Sagebrush	23.1	4.9	2.8	2.1	7.0	0.0	8.4	28.0
Low pinyon-juniper	28.7	2.1	5.6	3.5	2.8	7.0	8.4	32.9
High pinyon-juniper	26.6	7.0	1.4	0.0	2.8	4.2	0.0	28.0
Mixed mountain browse	26.6	-*	4.2	1.4	5.6	2.8	12.6	32.2

*Data collection not conducted due to inaccessibility of sample area (snow).

Table 3. Soil surveys for each of the four locations (Redente 1974).

Low Pinyon-Juniper Location (NE¼, SE¼, SE¼, Sec. 20, TIN, R97W)

A-1 0 to 3 cm Pale brown (10YR 6/3) channery loam, brown (10YR 4/3 moist; moderate and coarse grandular structure, soft dry, very friable moist, slightly sticky; calcareous; abrupt smooth boundary; (pH 8.6).

C-1 3 to 11 cm Pale brown (10YR 6/3) channery silt loam, dark yellowish borwn (10YR 4/4) moist; moderate very coarse platy breaking to moderate medium and coarse subangular blocky structure; slightly hard dry, friable moist, slightly sticky,slightly plastic, strongly calcareous; abrupt smooth boundary; (pH 8.8).

CR 11 to 24 cm White (10YR 8/1) dry, lime coating on brownish yellow to yellowish brown fractured and weathered platy shale rock.

R 24 cm+ Very hard and almost solid platy shale bedrock.

Remarks: The surface has about 30 to 50% cover of small channery chips ¼ to 1 inch in size and 1/16 to 3/16 inches thick. The A-1 and C-1 horizons contain many very fine visicular pores. The C-1 horizon also contains 15 to 30% of channery chips. The percent and thickness of the channery fragments will increase on the steep sideslopes of the ridges. The shale fragments in the CR and R horizons are lime coated and mainly on the underside.

Sagebrush Locaction (SE¼, NE¼, SE¼, Sec. 24, TIS, R99W)

A-11 0 to 4 cm Pale brown (10YR 6/3) loam, dark yellowish brown (10YR 4/4) moist; surface crusted with moderate coarse platy breaking to moderate medium and coarse subangular blocky structure; slightly hard dry, friable moist, slightly sticky, slightly plastic; weakly calcareous; abrupt smooth boundary; (pH 8.0).

A-12 4 to 9 cm Brown (10YR 5/3) loam, dark yellowish brown (10YR 3/4) moist; weak medium and coarse subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; weakly calcareous; clear smooth boundary; (pH 8.4).

C-1ca 9 to 38 cm White (2.5YR 8/2) heavy loam, pale yellow (2.5YR 7/4) moist; moderate medium subangular blocky structure; slightly hard dry; friable moist, sticky, plastic; strongly calcareous; clear smooth boundary; (pH 9.4).

Table 3. (Continued)

11-C2ca	38 to 52 cm Light gray (2.5YR 7/2) channery silt loam, light yellowish brown (2.5YR 6/4) moist; massive breaking to weak coarse subangular blocky structure; slightly hard dry, friable moist, sticky, slightly plastic; strongly calcareous; clear smooth boundary; (pH 9.6).
CR	52 to 74 cm Light yellowish brown (2.5YR 6.4) coarse channery and fine sandy loam, light olive brown (2.5YR 5/4) moist; weathered fractured sandstone, calcareous; gradual smooth boundary; (pH 9.2).
R	74 cm+ Weathered and fractured sandstone bedrock.
Remarks:	The A-11 horizon contains many visicular pores. The 11-C2ca contains 15 to 20% by volume channery fragments 1/4 to 1 inch in size and thickness. The CR horizon contains 40 to 65% of channery sandstone that ranges from 1/2 to 1-1/2 inches thick and 1 to 3 inches across.

High Pinyon-Juniper Location (NE¼, SE¼, NE¼, Sec. 13, T3S, R97W)

A-11	0 to 10 cm Brown (10YR 4/3) light loam, very dark grayish brown (10YR 3/2) moist; weak medium subangular blocky, breaking to moderate very fine to medium granular structure, soft dry, very friable moist, slightly sticky; non-calcareous; clear smooth boundary; (pH 8.4).
A-12	10 to 18 cm Grayish brown (10YR 5/2) light loam, dark brown (10YR 3/3) moist; weak to moderate medium and coarse subangular blocky structure; slightly hard dry, very friable moist; slightly sticky; weakly calcareous; clear smooth boundary; (pH 8.6).
C-2ca	18 to 40 cm Light brownish gray (2.5YR 6/2) channery, very fine sandy loam, grayish brown (2.5YR 5/2) moist; massive breaking to weak medium and coarse subangular blocky structure; slightly hard dry, very friable moist, slightly sticky; strongly calcareous; gradual smooth boundary; (pH 8.6).
CR	40 to 56 cm Light gray (2.5YR 7/2) lime coated weathered and fractured sandstone with some soil in cracks.
R	56 cm+ Sandstone bedrock. (Somewhat fractured).
Remarks:	Where the A horizon has been removed the surface has a channery cover of 20 to 30% and will range in size of 1/4 to 3 inches and 1/4 to 1 inch thick. The C-2ca horizon has 40 to 65% sandstone channery 1/4 to 2 inches across and 1/4 to 1 inch thick.

Table 3. (Continued)

Mountain Browse Location (NE¼, NE¼, NW¼, Sec. 14 T4S, R97W)

A-11	0 to 3 cm Grayish brown (10YR 5/2) very fine sandy loam, very dark grayish brown (10YR 3/2) moist; moderate medium to very coarse platy, breaking to weak to moderate fine and medium subangular blocky structure; soft dry, very friable moist, slightly sticky, slightly plastic, noncalcareous; abrupt smooth boundary; (pH 7.2).
A-12	3 to 12 cm Grayish brown (10YR 5/2) loam, very dark grayish brown (10YR 3/2) moist; moderate medium subangular blocky structure; slightly hard dry, friable, slightly sticky, slightly plastic; noncalcareous; clear smooth boundary; (pH 7.2).
CR	12 to 22 cm Grayish brown (10YR 5/2) channery loam, very grayish brown (10YR 3/2) moist; rock structure; (pH 7.4).
R	22 cm+ Pale brown to light yellowish brown sandstone (pH 7.6).
Remarks:	Channery fragments are found throughout and on the surface.

Table 4. Species seeded on four study locations.

Shrubs

Amelanchier utahensis - Serviceberry

Artemisia arbuscula nova - Black Sagebrush

Artemisia tridentata - Big Sagebrush

Atriplex canescens - Fourwing Saltbush

Atriplex confertifolia - Shadscale Saltbush

Atriplex gardneri - Gardner Saltbush

Atriplex nuttallii - Nuttall Saltbush

Ceanothus integerrimus - Ceanothus Deerbrush

Ceanothus prostratus - Ceanothus Squawcarpet

Cercocarpus betuloides - Birchleaf Mt. Mahogany

Cercocarpus ledifolius - Curl-leaf Mt. Mahogany

Cercocarpus montanus - True Mountain Mahogany

Chrysothamnus nauseosus - Rubber Rabbitbrush

Chrysothamnus viscidiflorus - Yellowbrush

Colubrina arborescens - Common Bladdersenna

Cowania stansburiana - Stansbury Cliffrose

Elaeagnus angustifolia - Russian Olive

Ephedra viridis - Green Ephedra

Eurotia lanata - Winterfat

Forestiera neomexicana - New Mexico Forestiera

Ilex verticillata - Winterberry

Kochia vestita - Desert Molly

Prunus fasciculata - Desert Peachbrush

Prunus virginiana melanocarpa - Black Chokecherry

Table 4. (Continued)

Purshia galndulosa - Desert Bitterbrush

Purshia tridentata - Antelope Bitterbrush

Rhus trilobata - Skunkbush Sumac

Sambucus caerulea - Blueberry Elder

Shepherdia argentea - Silver Buffaloberry

Symphoricarpos albus - Snowberry

Forbs

Aster chilensis adscendens - Pacific Aster

Aster spp. - Aster

Astragalus cicer, var. Lutana - Lutana Cicer Milkvetch

Astragalus falcatus - Sicklepod milkvetch

Balmorhiza sagittata - Arrowleaf Balsamroot

Coronilla varia, var. Penngift - Penngift Crownvetch

Hedysarum utahensis - Utah Sweetvetch

Linum lewisii - Lewis Flax

Lupinus alpestris - Mountain Lupine

Medicago sativa, var. Rambler - Rambler Alfalfa

Medicago sativa, var. Rhizoma - Rhizoma Alfalfa

Melilotus officinalis, var. Madrid - Madrid Yellow Sweetclover

Osmorhiza occidentalis - Sweetanise

Penstemon palmeri - Palmer Penstemon

Penstemon strictus - Rocky Mountain Penstemon

Sanguisorba minor - Small Burnet

Saponaria officinalis - Bouncing-bet

Table 4. (Continued)

Sphaeralcea grossulariaefolia - Gooseberryleaf Globemallow

Verbena spp. - Verbena

Grasses

Agropyron cristatum, var. Nordan - Nordan Crested Wheatgrass

Agropyron dasystachyum, var. Critana - Critana Thickspike Wheatgrass

Agropyron elongatum, var. Jose - Jose Tall Wheatgrass

Agropyron griffithsi - Griffiths Wheatgrass

Agropyron intermedium, var. Amur - Amur Intermediate Wheatgrass

Agropyron intermedium, var. Oahe - Oahe Intermediate Wheatgrass

Agropyron riparium, var. Sodar - Sodar Streambank Wheatgrass

Agropyron sibiricum - Siberian Wheatgrass

Agropyron smithii - C-30 Western Wheatgrass

Agropyron smithii, var. Barton - Barton Western Wheatgrass

Agropyron smithii, var. Rosana - Rosana Western Wheatgrass

Agropyron spicatum - Bluebunch Wheatgrass

Agropyron trachycaulum - Slender Wheatgrass

Agropyron trichophorum, var. Luna - Luna Pubescent Wheatgrass

Bromus carinatus - Mountain Brome

Bromus erectus, var. Regar - Regar Meadow Brome

Bromus inermis - Manchar Brome

Dactylis glomerata - Orchardgrass

Elymus cinereus, var. C-43 - C-43 Basin Wildrye

Elymus junceus, var. Sawki - Sawki Russian Wildrye

Elymus salinus - Salina Wildrye

Table 4. (Continued)

Festuca arizonica - Arizona Fescue

Festuca ovina, var. Durar - Durar Hard Fescue

Hilaria jamesii - Galleta Hilaria

Oryzopsis hymenoides - Indian Ricegrass

Phleum pratense - Timothy

Poa ampla, var. Shermans - Shermans Big Bluegrass

Poa pratensis - Kentucky Bluegrass

Sporobolus airoides - Alkali sacation

Sporobolus cryptandrus - Sand Dropseed

Stipa viridula - Green Needlegrass

Table 5. Average percent cover of planted and invading plants on the mid-elevation sagebrush site subjected to both favorable and unfavorable conditions on the 1972 planting. Data collected in July 1975 and 1976.

Species	Favorable		Unfavorable	
	P	S	P	S
Planted	.14	.12	.05	.04
Invaders				
Oryzopsis hymenoides[1]	.05	.10	.05	.03
Sphaeralcea coccinea	.04	.04	.01	.01
Stipa comata	.02	.03	.01	.01
Gilia congesta	.002	.02	.01	.03
Others*	.04	.08	.11	.12
Total of invading species	.15	.27	.19	.20
Total plant cover	.29	.39	.24	.24

*Other includes species which constitute little in individual total cover percentages. These included: Penstemon spp., Erigeron eatonii, Phlox longifolia, Poa spp., Townsendia incana, Phlox hoodii, Agropyron spp., Elymus spp., Astragalus spp., Sitanion longifolium, Allium teltile, Bromus techtorum, Lappula redowskii, Mustard spp., Haplopappus accaulis, Eriogonum spp., Descurainia sophia, Chenopodium fremontii, Lathyrus spp., Physaria floribunda, Chrysothamnus viscidiflorus, Cryptantha sericea, Euphorbia robusta, Haplopappus nuttallii, Crepis spp., and Atriplex spp.

[1]Common names in Appendix, Table 13.

Table 6 . Average percent cover of planted and invading plants on the mid-elevation sagebrush site subjected to both favorable and unfavorable conditions on the 1973 planting. Data collected in July 1975 and 1976.

Species	Favorable		Unfavorable	
	P	S	P	S
Planted	.10	.04	.17	.03
Invaders				
Oryzopsis hymedoides	.03	.07	.01	.13
Gilia congesta	.02	.03	.004	.01
Eriogonum umbellatum	.03	.04	.001	.002
Stipa comata	.01	.01	.001	.04
Bromus techtorum	.004	.01	.08	.01
Others*	.07	.08	.04	.10
Total of invading species	.16	.24	.14	.29
Total plant cover	.26	.28	.31	.32

*Others includes species which constitute little in individual total cover percentages. Haplopappus nuttallii, Sphaeralcea coccinea, Agropyron spp., Phlox longifolia, Bromus techtorum, Allium textile, Crepis spp., Eriogonum spp., Chenopodium fremontii, Penstemon spp., Astragalus spp., Lappula redowskii, Physaria floribunda, Lathyrus spp., Mustard spp., Cryptantha sericea, Senecio spp., Euphorbia robusta, Erigeron eatonii, Trifolium gymnocarpon, Oenothera spp., Linum lewisii, Hymenoxys richarsonii, Chaenactis douglasii, Salsola iberica, Sitanion longifolium, Poa spp., and Chrysothamnus viscidiflorus.

Table 7. Average percent cover of planted and invading plants on the low pinyon-juniper location subjected to both favorable and unfavorable conditions on the 1972 planting. Data collected in July 1975 and 1976.

Species	Unfavorable North		Favorable		Unfavorable South	
	P	S	P	S	P	S
Planted	.11	.14	.09	.10	.12	.13
Invaders						
Oryzopsis hymenoides	.04	.05	.07	.02	.02	.06
Haplopappus nuttallii	.01	.02	.03	.06	.05	.03
Chrysothamnus viscidiflorus	.03	.01	.01	.01	.01	.03
Linum lewisii	.01	.01	.02	.02	.01	.01
Others*	.06	.05	.04	.05	.09	.03
Total of invading species	.15	.14	.17	.16	.18	.16
Total plant cover	.26	.28	.26	.26	.30	.29

*Others includes species which constitute little in individual total cover percentages. These included: Mentha arvensis, Physaria floribunda, Bromus techtorum, Gilia congesta, Lathyrus spp., Phlox longifolia, Oenothera spp., Penstemon spp., Agropyron spp., Cryptantha sericea, Eriogon spp., Phlox hoodii, Hymenoxys richardsonii, Euphorbia robusta, Haplopappus accaulis, Astragalus spp., Circium spp., Stipa comata, Erigeron eatonii, Mustard spp., Lappula redowskii, Senecio spp., Tetradymia spp., Artemesia tridentata.

Table 8. Average percent cover of planted and invading plants on the low pinyon-juniper location subjected to both favorable and unfavorable conditions on the 1973 planting. Data collected in July 1975 and 1976.

Species	Unfavorable North		Favorable		Unfavorable South	
	P	S	P	S	P	S
Planted	.05	.06	.05	.06	.07	.08
Invaders						
Oryzopsis hymenoides	.01	.02	.01	.02	.04	.03
Haplopappus nuttallii	.01	.01	.01	.01	.004	T
Chrysothamnus viscidiflorus	.01	.01	.001	.01	-	.001
Mentha arvensis	.001	-	.002	.01	.04	.03
Others*	.04	.03	.05	.06	.04	.04
Total of invading species	.07	.07	.09	.10	.12	.10
Total plant cover	.12	.13	.14	.16	.19	.18

*Others includes species which constitute little in individual total cover percentages. These included: Penstemon spp., Mustard spp., Bromus techtorum, Sphaeralcea coccinea, Physaria floribunda, Linum lewisii, Haplopappus accaulis, Crepis spp., Hymenoxys richardsonii, Erigeron eatonii, Phlox hoodii, Agropyron spp., Gilia congesta, Lappula redowskii, Stipa comata, Astragalus spps., Senecio spp., Euphorbia robusta, Oenothera spp., Eriogonum spp., Opuntia spp.

Table 9. Average percent cover of planted and invading plants on the high pinyon-juniper location subjected to both favorable and unfavorable conditions on the 1972 planting. Data collected in July 1975 and 1976.

Species	Favorable		Unfavorable	
	P	S	P	S
Planted	.15	.14	.12	.15
Invaders				
Oryzopsis hymenoides	.14	.17	.15	.15
Aster canescens	.05	.01	.02	.01
Bromus techtorum	.02	.01	.06	.04
Others*	.06	.13	.06	.09
Total of invading species	.27	.32	.29	.29
Total plant cover	.42	.46	.41	.44

*Others includes species which sonstitute little in individual total cover percentages. These included: Agoseris glauca, Physaria floribunda, Chaenactis douglasii, Agropyron spp., Carex spp., Sphaeralcea coccinea, Chrysothamnus viscidiflorus, Astragalus spp., Penstemon spp., Haplopappus nuttallii, Stipa comata, Linum lewisii, Bromus techtorum, Taraxacum officinale, Senecio spp., Chenopodium fremontii, Eriogonum spp., Sitanion longifolium, Koeleria gracilis, Antennaria rosea, Hordeum jubatum, Gilia aggregata, Descurainia sophia, Phlox hoodii, Oenother spp., and Lathyrus spp.

Table 10. Average percent cover of planted and invading plants on the high pinyon-juniper location subjected to both favorable and unfavorable conditions on the 1973 planting. Data collected in July 1975 and 1976.

Species	Favorable		Unfavorable	
	P	S	P	S
Planted	.06	.04	.04	.05
Invaders				
Oryzopsis hymenoides	.15	.13	.08	.16
Bromus techtorum	.31	.32	.47	.38
Others*	.06	.06	.03	.04
Total of invading species	.58	.55	.62	.63
Total plant cover	.58	.55	.62	.63

*Others includes species which constitute little in individual total cover percentages. These included: Lappula redowskii, Aster canescens, Salsola iberica, Collinsia parviflora, Hordeum jubatum, Haplopappus nuttallii, Mustard spp., Cryptatha sericea, Gilia aggregata, Taraxacum offincinale, Chrysothamnus viscidiflorus, Chaenactis douglasii, Astragalus spp., Physaria floribunda, Descurainia sophia, Senecio spp., Stipa comata, Sphaeralcea coccinea, Agropyron spp., and Carex spp.

Table 11. Average percent cover of planted and invading plants on the mountain browse location subjected to both favorable and unfavorable conditions on the 1972 planting. Data collected in July 1975 and 1976.

Species	Favorable		Unfavorable	
	P	S	P	S
Planted	.12	.19	.23	.11
Invaders				
Lupinus spp.	.12	.12	.02	.04
Astragalus spp.	.05	.05	.04	.04
Agropyron spp.	.03	.02	.01	.03
Others*	.23	.26	.23	.25
Total of invading species	.43	.45	.30	.36
Total plant cover	.55	.64	.53	.47

*Others on this site were so numerous that only the major components were included. Other species found included: Chenopodium fremontii, Bromus techtorum, Crepis spp., Penstemon spp., Collinsia parviflora, Collomia linearis, Oryzopsis hymenoides, Chrysothamnus viscidiflorus, Trifolium gymnocarpon, Balsamorhiza sagittata, Poa spp., Sphaeralcea coccinea, Amelanchier alnifolia, Comandra umbellata, Phlox Longifolia, Mertensia ciliata, Artemesia tridentata, Senecio spp., Koeleria gracilis, Eriogonum umbellatum, Bromus marginatus, Lathyrus leucanthus, Lomatium greyi, Stipa comata, Phlox multiflora, Symphoricarpos oreophilus, Taraxacum officinale, Tetradymia spp., Chaenactis douglasii, Physaria floribunda, Aster canescens, Festuca spp., Allium textile.

Table 12. Average percent cover of planted and invading plants on the mountain browse location subjected to both favorable and unfavorable conditions on the 1973 planting. Data collected in July 1975 and 1976.

Species	Favorable		Unfavorable	
	P	S	P	S
Planted	.10	.09	.16	.13
Invaders				
Lupinus spp.	.21	.10	.17	.02
Collinsia parviflorus	.04	.01	.01	.01
Agropyron spp.	.002	.01	.02	.03
Phlox multiflora	.004	.02	.01	.03
Astragalus spp.	.02	.01	.01	.03
Others*	.11	.21	.13	.22
Total of invading species	.39	.36	.35	.34
Total plant cover	.49	.45	.46	.47

*Others on this site were so numerous that only the major components were included. Other species found included: Chenopodium fremontii, Collomia linearis, Chrysothamnus viscidiflorus, Trifolium gymnocarpon, Erigeron eatonii, Crepis spp., Poa spp., Oryzopsis hymenoides, Bromus techtorum, Penstemon spp., Symphoricapos oreophilus, Amelanchier alnifolia, Artemesia tridentata, Phlox longifolia, Balsamorhiza sagittata, Lappula redowskii, Lomatium greyi, Agoseris glauca, Gilia aggregata, Sphaeralcea coccinea, Comandra unbellata, Arabis spp., Taraxcum officinale, Lathyrus leucanthus, Stipa comata, Chaenactis douglasii, Erysimum capitatum, Koeleria gracilis, and Trifolium gymnocarpon.

Table 13. Species identified in the Piceance Creek Basin.

Trees

Juniperus osteosperma (Torr.) Little; Utah Juniper

Juniperus scopulorum Sarg.; Rocky Mountain Juniper

Pinus edulis Engelm.; Pinyon Pine

Shrubs

Amelanchier alnifolia Nutt.; Saskatoon Serviceberry

Artemisia frigida Willd.; Fringed Sagebrush

Artemisia ludoviciana Nutt.; Louisiana Sagewort

Artemisia tridentata Nutt.; Big Sagebrush

Atriplex canescens (Pursh) Nutt.; Fourwing Saltbush

Atriplex confertifolia (Torr. & Fremont) S. Wats.; Shadscale

Cercocarpus montanus Raf.; True Mountain Mahogany

Chrysothamnus depressus Nutt.; Dwarf Rabbitbrush

Chrysothamnus nauseosus (Pall.) Britt. in Britt. & Brown; Rubber Rabbitbrush, Big Rabbitbrush

Chrysothamnus viscidiflorus (Hook.) Nutt.; Douglas Rabbitbrush, Little Rabbitbrush

Eurotia lanata Pursh; Winterfat

Opuntia erinacea Engelm. & Bigelow; Prickly Pear Cactus

Opuntia fragilis (Nutt.) Haw; Brittle Prickly Pear Cactus

Purshia tridentata (Pursh) DC; Antelope Bitterbrush

Rosa woodsii Lindl.; Wild Rose

Symphoricarpos oreophilus A. Grey; Mountain Snowberry

Tetradymia canescens DC; Gray Horsebrush

Table 13. (Continued)

Forbs

Achillea lanulosa Nutt.; Western Yarrow

Agoseris glauca (Pursh) Raf.; Mountain Dandelion

Allium acuminatum Hook.; Tapertip Onion

Allium nevadense S. Wats.; Nevada Onion

Allium textile Nels. & Macbr.; Textile Onion

Amaranthus graecizans L.; Prostrate Pigweed

Antennaria rosea Greene; Rose Pussytoes

Arabis spp. L.; Rockcress

Arenaria eastwoodiae Rydb.; Sandwort

Artemisia ludoviciana Nutt.; Louisiana Sagebrush

Aster arenosus Blake; Sand Aster

Aster canescens Pursh; Hoary Aster

Astragalus chamaeleuce A. Gray; Locoweed, Milkvetch

Astragalus cicer Dougl. ex Hook.; Locoweed, Milkvetch

Astragalus diversifolius A. Gray; Locoweed, Milkvetch

Astragalus kentrophyta A. Gray; Locoweed, Milkvetch

Astragalus lutosus M. E. Jones; Locoweed, Milkvetch

Astragalus miser (Rydb) Cronquist; Locoweed, Milkvetch

Astragalus purshii Dougl. ex Hook.; Locoweed, Milkvetch

Astragalus spatulatus Sheld.; Locoweed, Milkvetch

Astragalus tennellus Pursh; Looseflower Milkvetch, Locoweed

Balsamorhiza sagittata (Pursh) Nutt.; Arrowleaf Balsamroot

Calochortus gunnisonii S. Wats.; Gunnison Mariposa

Calochortus nuttallii Torr.; Segolily

Table 13. (Continued)

Camelina microcarpa Andrz.; Falseflax

Capsella bursa-pastoris (L.) Medic.; Shepherd's Purse

Carex geyeri Boott; Elk Sedge

Carex rossii Boott in Hook.; Ross Sedge

Castilleja chromosa A. Nels.; Indian Paintbrush

Castilleja linariaefolia Benth in DC.; Wyoming Painted Cup

Chaenactis douglasii (Hook.) Hook. & Arn.; Douglas Pincushion

Chenopodium fremontii S. Wats.; Lamb's Quarters

Cirsium eatonii (A. Grey) Robinson; Canada Thistle

Cirsium undulatum (Nutt.) Spreng.; Wavyleaf Thistle

Collinsia parviflora Dougl. in Lindl.; Blue-eyed Mary

Collomia linearis Nutt.; Slenderleaf Collomia

Comandra umbellata (A. DC.) Piehl.; Bastard Toadflax

Crepis acuminata Nutt.; Tapertip Hawksbeard

Crepis intermedia A. Gray; Gray Hawksbeard

Crepis occidentalis Nutt.; Western Hawksbeard

Cryptantha sericea (A. Gray) Payson; Cryptantha

Delphinium nelsonii Greene; Low Larkspur

Delphinium occidentale (S. Wats.) S. Wats.; Tall Mountain Larkspur

Descurainia sophia (L.) Webb ex Prantl; Flixweed Tansey Mustard

Erigeron eatonii A. Gray; Eaton Fleabane, Creeping Daisy

Erigeron speciousus (Lindl.) DC; Oregon Fleabane

Eriogonum alatum Torr.; Wing Eriogonum

Eriogonum lonchophyllum T. & G.; Eriogonum

Eriogonum umbellatum Torr.; Sulfar Eriogonum

Table 13. (Continued)

Erysimum capitatum (Dougl.) Greene; Wallflower

Euphorbia robusta (Engelm.) Small; Robust Euphorbia

Galium boreale L.; Northern Bedstraw

Geranium richardsonii Fisch. & Trautv.; Richardson Geranium

Gilia aggregata (Pursh) Spreng., Syst.; Scarlet Gilia

Gilia congesta Hook.; White Gilia

Haplopappus acaulis (Nutt.) A. Gray; Stemless Goldenweed

Haplopappus nuttallii T. &. G.; Goldenweed, Gumweed

Hedysarum boreale Nutt.; Northern Sweetvetch

Hymenoxys acaulis (Pursh) Parker; Stemless Hymenoxys

Hymenoxys richardsonii (Hook.) Ckll.; Richardson Hymenoxys

Lactuca serriola L.; Prickly Lettuce

Lappula redowskii (Hornem.) Greene; Annual Stickweed

Lathyrus leucanthus Rydb.; Aspen Pea-Vine

Lepidium montanum Nutt.; Pepperweed

Lepidium perfoliatum L.; Clasping Pepperweed

Leptodactylon Pungens (Torr.) Rydb.; Prickly-Phlox

Linum lewisii Pursh; Lewis Flax

Lomatium grayii C. & R.; Desert Parsley

Lomatium simplex (Nutt.) MacBride; Nineleaf Lomatium

Lupinus argenteus Pursh; Silvery Lupine

Lupinus caudatus Kellogg; Tailcup Lupine

Medicago sativa L.; Alfalfa

Melitlotus officinalis (L.) Lam.; Yellow Sweetclover

Mentha arvensis L.; Field Mint

Table 13. (Continued)

Mentzelia albicaulis Dougl. ex Hook.; Whitestem Mentzelia

Mentzelia humilis (Gray) Darlington, Ann; Stickleaf

Mertensia ciliata (James) G. Don; Mountain Bluebells

Oenothera caespitosa Nutt.; Evening Primrose

Oenothera coronopifolia T. & G.; Evening Primrose

Oxytropis lambertii A. Gray; Lambert Crazyweed

Penstemon osterhoutii Pennell; Penstemon

Penstemon strictus Benth. in DC.; Penstemon

Penstemon teucriodes Greene; Penstemon

Penstemon watsonii A. Gray; Watson Penstemon

Phlox hoodii Rich.; Hoods Phlox

Phlox multiflora A. Nels.; Flowery Phlox

Physaria floribunda Rydb.; Twinpod

Potentilla gracilis (Lehm.) Fernald; Northwest Cinquefoil

Ranunculus cymbalaria var. saximontanus Ferald; Rocky Mountain Buttercup

Rumex salicifolius Weinm.; Willow Dock

Salsola iberica Sennen & Pau; Russian Thistle

Schoenocrambe linifolia (Nutt.) Greene; Hedge Mustard

Senecio integerrimus Nutt.; Lambstongue Groundsel

Senecio multilobatus T. & G. ex A. Gray; Lobeleaf Groundsel

Senecio serra Hook.; Butterweed Groundsel

Senecio wootonii Greene; Groundsel

Sisymbrium altissimum L.; Tumblemustard

Sphaeralcea coccinea (Pursh) Rydb.; Scarlet Globemallow

Streptanthus cordatus Nutt. ex T. & G.; Heartleaf Twistflower

Table 13. (Continued)

Taraxacum officinale Web. in Wiggers; Common Dandelion

Thalictrum fendleri Engelm. ex A. Gray; Meadowrue

Thlaspi montanum L.; Pennycress

Townsendia incana Nutt.; Hoary Townsendia

Tragopogon dubius (Jacq.) Vollman; Goatsbeard

Trifolium gymnocarpon Nutt.; Hollyleaf Clover

Vicia americana Muehl. ex Willd.; American Vetch

Viola nuttallii Pursh; Nuttall Violet

Wyethia amplexicaulis Nutt.; Mulesears

Zygadenus venenosus (Rydb.) Walsh ex M. E. Peck; Death Camas

Grasses

Agropyron desertorum (Fisch.) Schult.; Crested Wheatgrass

Agropyron elongatum (Host.) Beauv.; Tall Wheatgrass

Agropyron intermedium (Host.) Beauv.; Intermediate Wheatgrass

Agropyron smithii Rydb.; Western Wheatgrass

Agropyron spicatum Heller; Bearded Bluebunch Wheatgrass

Agropyron trachycaulum (Link) Richt.; Slender Wheatgrass

Bouteloua gracilis (H. B. K.) Lag.; Blue Gramma

Bromus inermis Leyss; Smooth Brome

Bromus marginatus Nees; Big Mountain Brome

Bromus tectorum L.: Cheatgrass Brome

Carex geyeri Boott; Elk Sedge

Carex rossii Boott in Hook.; Ross Sedge

Festuca spp. L.; Fescue

Table 13. (Continued)

Hordeum jubatum L.; Foxtail Barley
Koeleria gracilis Pers.; Junegrass
Oryzopsis hymenoides (R. & S.) Ricker; Indian Ricegrass
Poa canbyi (Scribn.) Piper; Canby Bluegrass
Poa fendleriana (Steud.) Vasey; Mutton Bluegrass
Poa pratensis L.; Kentucky Bluegrass
Poa secunda Presl.; Sandberg Bluegrass
Sitanion longifolium J. G. Smith; Squirrelltail
Stipa columbiana Macoun.; Subapline Needlegrass
Stipa comata Trin. & Rupr.; Needle-and-Thread
Stipa lettermanii Vasey; Letterman Needlegrass